STUDIES ON TASTE AND FOOD PREFERENCES AND BAIT-SHY BEHAVIOUR OF 'ROOF' RAT, *RATTUS RATTUS* L.

THESIS SUBMITTED FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

ZOOLOGY

By

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ALIGARH (INDIA)

April, 1981

ABSTRACT

Rattus rattus L., variously called "black" rat, "roof" rat or "house" rat; is a serious pest in both rural and urban areas, practically all over India and similarly throughout the tropics. Highly adaptable, it colonises all possible situations; exacts a slow toll in form of food, besides causing extensive structural damages. Further, contaminates and spoils the food it is not able to consume, and transmits diseases to man. Yet, like many other problems, infestation by rodent pests is ignored in India; as elsewhere in the third world.

Efforts to control or eradicate the pest, are beset with many hurdles; of which some are unique. The most glaring concerns the selection of "baits" or of foods to serve as vehicles for poison meant to kill them. Foods preferred in one population can be liked less in the other. Further, like feeding, other kinds of behaviour in this species show great "plasticity". Reactions to baits, additives, containers and responses to poisoned baits, are not likely to be always similar. Viewed in regional context, problems obviously become compounded, and assume great intricacy and complexity.

can be obtained with each food added to it.

Zinc phosphide is, however, used in much higher concentrations (c.50-500 mg/10 g food) in the field. Tests in field are required to testify the utility of methods explained.

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Detailed ecological and behavioural investigations are, therefore, required of different colour "morphs" , and of each "population" seperately. The present observations of "rufescens", of both it's rural and urban populations, appear, therefore, very important and timely.

TASTE THRESHOLDS:

Tested by original "preference" method, "roof" rats are found to discriminate taste solutions at concentrations lower than the standards described for laboratory rats. Thus, the four stimulants - quinine sulfate, citric acid, sucrose, sodium chloride; remain effective at concentration respectively of 0.0005%, 0.01%, 0.05%, 0.1% in "laboratory" colonies; and 0.0005% , 0.01%, 0.025% and 0.01" in "free-living" colonies. Only the threshold concentration of sodium chloride is higher in comparison to taste threshold for it analysed in laboratory rats.

Obviously, tasting ability is more acute in "free-living" state rather than under captivity; which is clear hint to it's survival value.

CONSUMMATORY INTAKES OF SUGARS:

"Roof" rats seem to like sugars, obviously because of it's taste, to a marked extent. Preference varies, however, with concentration. Large amounts are ingested in hypotonic range; consumption is reduced only as increasing hypertonicity makes them intolerable. Thus, consummatory intakes are charachterised by the fact that taste is able to overpower post-ingestive effects of sugars to a certain extent.

"Marked" preference is, however, shown over a wider range of concentrations for sucrose and glucose (1.209 to 17.8%) than for either maltose (1.209 to 15.85%), jaggery (1.209 to 14.13%) or fructose (1.209 to 12.59%). These differences are based on their relative sweetness. Lactose is rejected at all concentrations.

Optimum choice for sugars is demonstrated upto about 12 to 15% strength. These are the limits to which sugar concentration in baits can be varied for obtaining maximum effect.

SUGAR PREFERENCES:

All kinds of common sugars are not equally liked by "roof" rats. Tested in choice situation at equal or 5% strength, sugars are selected in order glucose > sucrose > jaggery > fructose > lactose in laboratory colonies; but in a different sequence - sucrose > jaggery > glucose > fructose > lactose, by "free-living" rats.

Taste or sweetness influences the choice for sugars in "free-living" condition; while post-ingestive consequences determine selection when rats are restricted to cages.

It appears from results of choice tests obtained in field that jaggery can be successfully used as additive instead of costlier sugars as sucrose, to increase preference for baits devised for "roof" rats.

FOOD REQUIREMENT:

Food consumption remains high at earlier stages of growth, in juveniles and sub-adults; but declines and levels off in older age-groups. The exponential relation between consumption (y) and body-weight (w) follows the equation: $y = 0.3464\ w^{0.3853}$. On the basis, consumption/rat in a Aligarh city population of known weight structure, is calculated to be 13.5g.

It suggests that "take" of bait recorded (g) in a population or colony of "roof" rats can be translated into rat numbers by dividing it by factor of 14.

FOOD PREFERENCES OF 'FREE-LIVING' RATS:

Urban rats are not easily attracted to any but the most effecient baits, as moist foods. In contrast, rats of rural populations accept all kinds of foods; often even the hardest, as pulses that are otherwise declined. In either case, baiting from surface gives better results than use of boxes or containers. Of other factors that influence baiting results, "disturbances in environment" are most important among external and physiological factors among internal factors.

Feeding behaviour components also influence the results. "Method of eating" has relevance for both the types of food and container used. Omnivory induces eating of baits, while "sampling behaviour" seems to initiate feeding and regulate the amounts consumed.

Given a choice, one of the two foods is clearly selected by "free-living" rats; equivocal choices are seldom shown. Selection follows in linear orders, but the choice for individual foods is not exactly similar to that observed earlier in laboratory tests. Evidently, social factors influence the choice to much greater extent than factors as taste, texture or energy value. Foods eaten in the environment are more preferred; but foods of high energy value find greater acceptance than foods of superior taste or texture.

"Takes" translated into rat number, do not give accurate estimates of population. Population trends are, however, adequately reflected by food consumption data. Thus, two unequal peaks of reproduction are demonstrated in fort colony (rural); the larger one following and smaller preceeding the winter season (November to February). Rat pups found near the food trays, corborated the occurrence of breeding both times.

Ectoparasites are recorded in rural population. Abundant during the rainy season, they disappear by start of winter. Natural mortality is, however, rare. Apparently, predators prevent rat population explosions in both rural and urban areas.

BAIT- SHYNESS:

Laboratory observations of the effects of sub-lethal doses of poison zinc phosphide (2 mg or 4 mg/10 g food), clearly show that "roof" rats trapped from all environments in Aligarh city rapidly develop "poison" and "bait-shyness". The preferred food when mixed with poison is declined (poison-shyness). It is also consistently rejected afterwards, i.e. without poison (bait-shyness). Evidently, discriminated against taste; the tastes of toxic mixture and of the food used in it as base, become, by association with poisoning, the basis of avoidance. However, the properties of poison are also important. These determine the type of response that follows.

The behaviour is similar to that developed by other species of wild rats studied, particularly the "Norway" rat.

EFFECT OF TEXTURE OF FOOD ON BAIT-SHY BEHAVIOUR:

Rats poisoned in cereal flours become averse to eating it afterwords; but their preference for textural variants of the same food, or whole cereals, is not affected. Similar results are obtained by using whole and husked form of pulses. Poisoning in one form does not effect the preference of bait-shy rats for other form of the same pulse.

In case of lentil and gram, however, poisoning in flour affects the preference of "bait-shy" rats for other form - husked lentil and gram; which are rejected. It appears, therefore, that textural variations involving seed structures (pericarp and testa), result in alteration of taste of food as well. This prevents the rats from associating poisoning to different textural forms of such foods. Thus, by using cereals and pulses in different forms; shyness can be avoided.

RESPONSES TO NON-OILY FOODS AFTER POISONING IN OILY FOODS:

After poisoning in oily foods (millet flour + groundnut - oil, maize flour + oil), shyness is not exactly broadened to non-oily foods, or the original bases (millet flour, maize flour). The latter are even slightly preferred by 'bait-shy' rats, suggesting that probably the oil exerts a "masking effect" on taste of cereal bases; which are thus not distinctly perceived by rats in oily mixture. Therefore, shyness is reduced; or foods used or added to mixture are avoided only partially.

RESPONSES TO FOODS USED IN A MIXTURE FOR POISONING:

Treatments with zinc phosphide in equivalent wt./wt. cereal mixtures - millet + maize flour, or millet + maize + wheat flour; make the rats not only averse to eating of original baits, but each food added is also rejected by them when offered seperately in harmless form.

Apparently, shyness is extended on the basis of distinct tastes of each food; which are thus clearly perceived in the mixture.

One poisoning in mixtures can make several baits ineffective.

BAITING SCHEMES AND BAITS DEVISED TO AVOID SHYNESS:

Methods of avoiding or eliminating shyness are not presently known. New baiting schemes with a change in poisoning schedules, instead of continuous treatment now followed, have often been suggested for this purpose.

However, it is found that poisoning at intervals of 3 or 6 days in the baits being preferentially eaten, fails to prevent the development of avoidence responses. After a lag, the baits are eaten by the rats in smaller amounts on 'poison-free' days. Thus, intermittent poisoning does not confer any advantages as visualised; poisons and baits become ineffective, as otherwise.

It is, however, possible to avoid shyness by poisoning rats in specially devised bait -mixtures of cereals containing oil. Thus, after treatments in millet + maize flour + oil or millet + maize + wheat flour + oil, the original baits are declined; but non-oily bait -mixture and it's components, are again preferentially eaten by them. Apparently, the rats fail to discriminate between the foods added to mixtures, because of 'masking' effect of oil. Shyness is thus not broadened to non-oily foods after poisoning in mixtures of the same foods with oil.

It appears, therefore, that practical difficulties encountered because of the development of such behaviour, of shyness, by the rats can be overcome to certain extent by methods described here. Thus, the baits as cereal and pulses can be used in alternative textureal forms (flour, whole grains; whole grains, husked grain) to avoid shyness. Similarly, it can be reduced by adding oil to bait-bases. If the oil is used in mixtures of cereals, more poisonings

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CERTIFICATE

This is to certify that the present work was done by Mr. Devendra Bhardwaj under my supervision.

The work is original, and greatly advances in my view the knowledge existing before in the same field.

I am, therefore, very pleased in allowing Mr. Devendra Bhardwaj to submit this work for award of Ph.D. degree to him.

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CONTENTS

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ACKNOWLEDGEMENTS

I am greatly indebted to Dr. Jamil Ahmad Khan for supervising this work. I am thankful to Professor S. M. Alam, Head, Department of Zoology, Aligarh Muslim University, for providing necessary laboratory facilities.

Thanks are also due to Aligarh Muslim University for financial assistance.

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INTRODUCTION

Rodents are one of the most successfull groups in class Mammalia (Southwick, 1969). Although adaptable to every environment, they are perhaps more abundant in tropics than in temperate areas (Tewari & Biswas, 1969). Thus, the fauna within India's geographical limits is also highly varied; comprising of 6 families, 36 genera, 84 species and of about 265 sub-species (Ellermann, 1947, 1963; Tewari & Biswas, 1969). Of them, however, only 16 species have been considered as economically very important (Barnett & Prakash, 1975).

However, species commensal with man invite greater attention in this regards (Spillet, 1968). Thus, commensal rodents are important, (1) as pests of stored food, (2) carriers of diseases and parasites of man and his domestic animals, (3) and for diverse structural damage caused to the environments infested (Barnett & Prakash, 1975). Evidently, some of them have been more thoroughly studied than any other non-human mammal (Barnett, 1975). However, rodents pests have not attracted much attention in India (Barnett & Prakash, 1975).

This is surprising for not less than a quarter of food grown in the country, is destroyed by the rodents (Spillet, 1968). Similarly, the number of rodent-borne diseases prevelent is not less than 50 (Patanaik, 1969; Barnett & Prakash, 1975). Bubonic plague is most notable of them; though now very rare (Suri, 1977). Other disease go almost unnoticed. Although rodents cause human misery, they are never-thless ignored in the third world.

It is only recently that a slogan of "war against rats", was given in India. Despite popularisation, the compaign fell through. It failed primarily because of the shortage of trained workers, as predicted before (Spillet, 1968); but almost equally perhaps due to paucity of informations about biology and behaviour of even the most common forms, including Rattus rattus L. So as for control methods, there was still less to be had (Prakash, 1976).

The present work conducted during the period 1973-1978, forms part of a larger enquiry into ecology and behaviour of rodent pests found in and in vicinity of Aligarh. It mainly deals with the applied aspects of the behaviour of "roof" rats, R. rattus. It is divided into 11 Chapters; of which the first Chapter deals with "tasting ability", the next two with "taste preferences"; and IVth & Vth Chapters with food consumption, and selection of foods by "free living_rats".

The last five Chapters (VI to XI) give an account of studies on "poison-shyness; and "bait-shy" behaviour of "roof" rats. As a phenomenon that protects the rats against poisoned-baits, or attempts to kill them in their natural environmnet, it has great survival value. However, the behaviour is disadvantageous from an applied view-point. Thus, the matter enclosed gives a description of efforts made towards elimination of "shyness". The results provide an important breakthrough (Chapter XI); but confirmation of this from field tests is still required.

HISTORICAL REVIEW

Rattus rattus (Linnaeus) - the common Indian rat, is almost a cosmopoliton species; occuring all over India and adjacent countries in both wild and commensal state (Tewari & Biswas, 1969). It exists, however, in several "colour morphs", also recognized as sub-species; of which at least fourteen are currently known within the territories of the Indian union (Tewari & Biswas, 1969; Barnett & Prakash, 1975). The most common type is *Rattus rattus rufescens*; dark-brown to black above, off-white to slightly lemon below (Prakash, 1963; Bhattacharya, 1973; Tewari, et. al., 1971; Cowan & Prakash, 1977).

Variously called as "black" rats, "roof" rat and more popularly as "house" rat, it is closely associated with man and found in his immediate surroundings. Adapted thus from fields to storehouses and larders (Barnett & Prakash, 1975), the urban rodent population in India, still largely consists of this species (Harris, 1969). A change has, however, been noticed since the early 60's, specially in big cities; where the lesser 'bandicoot' rat, *Bandicota bengalensis* Gray, has successfully invaded and excluded it from most environmnets (Rao, 1947; Seal, 1960; Deoras, 1960, 1963, 1969; Spillet, 1968; Seal & Bannerjee, 1969).

R. rattus, is largely "arboreal" in the sense that it lives mostly above ground (Barnett, 1975). Tree-holes, crevices in buildings, corners and hollowed walls; are it's usual nesting sites (Watson, 1954; Rajgopalan et. al., 1970 ; Barnett & Prakash, 1975). Nesting has been recorded in unusual situations too (Sharma & Sivaram, 1966); while it's occurence has been disputed altogether in other situations (Barbehenn, 1962).

Like other commensal rodent pests, it has been found highly omnivorous in feeding habits (Barnett & Prakash, 1975). Literature on the subject has been reviewed by Parrack (1967); but more to it has been added since, largely though by way of observations in laboratory (Deoras, 1968; Majumdar et. al., 1969; Khan, 1974). There is a dearth of field studies; although most habitats it lives in, are ideally suited, as also demonstrated in this study, for long-term observations of it's feeding.

There is relatively much more information available on reproduction, sex-ratios, population estimates, structure and dynamics, and mortality of this species; from many parts of the world (listed by Parrack, 1967; Barbehenn, 1962; Southwick, 1969). Recent studies of the kind from India have been very few (Rajgopalan, 1971); and large-scale observations are thus urgently required. Growth of R. rattus has, however, been followed in considerable detail in the laboratory (Spillet, 1969).

R. rattus, has a "parasito-fauna" similar to that of other species sympatric to it. It includes the usual ectoparasites, mostly fleas; and a large number of internal parasites, of all kinds - nematodes, cestodes, trematodes etc. (Prakash, 1954; Deoras & Tonpi, 1956; Aziz, 1965, Deoras, 1965a; Deoras, 1965b; Chandrahas & Krishnaswami, 1971; Dhar et al., 1972). Often very high rates of infestation by fleas have, however, been recorded (Chaturvedi & Deoras, 1972); though nothing has been done to find the incidence of internal parasites.

Found positive to several kinds of infection transmittable to man and his domestic animals (Soman, 1950; Sharma et al., 1970); it's susceptibility to plague is better known. Yet, they seem to be less susceptible than bandicoots or species that is replacing it (Deoras, 1960; Seal, 1960; Nimbalkar et. al., 1971). Thus, there is no great danger from "roof" rats as for "reintroduction" of plague in the subcontinent. Neverthless epidemiological studies of it have continued, as also required (Seal, 1960, 1961; Bhatnagar, 1969; Nimbalkar et. al., 1971; Renapurkar , 1971; Krishnaswami et. al., 1972; Nimbkar et. al., 1973).

Investigations relating to control of "roof" rats have obviously been given greater attention. Thus, toxicity of a wide variety of poison to it has been evaluated (Deoras, 1965a, 1967; Krishnakumari, 1968; Muktabai et. al., 1971; Grish et. al., 1972; Renapurkar & Sant, 1974); alongwith with the study of susceptibility and tolerance to anticoagulants (Deoras, 1965b, 1966, 1967; Krishnamurthy et. al., 1968; Chaturvedi et. al., 1977; Prakash & Mathur, 1979; Sood & Dilber, 1980, Rana & Mathur, 1980). Some work has also been done on repellents and fumigants (Majumdar et.,al., 1964; Krishnakumari et. al., 1971). Results of large scale poisoning operations in the field have also been reported (Tirimalrao, 1950; Kapoor, 1965; Deoras, 1968; Singh et. al., 1965; Krishnamurthy et. al., 1968, 1969, 1971a, 1971b; Rao et. al., 1977; Dharamraju, 1977; Chaturvedi et. al., 1977).

Acceptability of poisoned-baits has been tested (Krishnakumari et. al., 1972); and similarly, the shyness developed to poisons and baits has also been observed (Prakash et. al., 1975). However, more studies on 'bait-shyness' are needed; obviously, on account of it's importance for control of 'rats' in field. This aspect of the behaviour of the species has been dealt with thus in detail in the present work.

Apart from such components of practical importance, very little effort has been made to study the behaviour of this species; though excellant works on it have appeared from elsewhere (Ewer, 1971; Cowan & Barnett, 1975 etc.).

Realizing the gaps as they exist in study of this species in India; tasting ability, taste preferences, food preferences and 'bait-shy', behaviour of the species, ~~have~~ been mainly studied.

OBJECTIVES

The overall objective of this research was to study such aspects of feeding behaviour of the species *Rattus rattus* that are important for our efforts to control it. The specific objectives were :

I. 1. To determine the threshold range for each of the four basic type of "taste" stimulants, viz. sweet, sour, salty and alkaline; so that the "tasting ability" was known for practical purposes, e.g. the capacity to discriminate between poisonous mixture and it's plain equivalent.

2. To find the effect of concentration on consummatory intakes of sugars, an additive commonly used to increase preference for cereal foods (baits); so that strengths of "optimum effectiveness" were obtained for applied work.

3. Find the choice of rat between common sugars; in order to demonstrate that common crude sugar or "Jaggery", which is cheaper, can be used instead of costlier cane-sugar.

II. 1. To investigate the relationship between food consumption and body-weight, and establish a formula by which food consumption could be translated into rat numbers for census work.

2. Determine the choice of rats for different kinds of foods in their natural environment, or logically extend the numerous observations of the kind made hitherto in the

laboratory. Based on this or with informations about factors that determine choice in field, better results can be obtained thus, in poison-baiting, or control operations against this pest.

III. To devise baiting schemes, or design baits which help to eliminate "shyness" developed by Rats; but without losing sight of the practicability of methods during actual operations in the field.

P A R T - A

CHAPTER - I

Taste Thresholds in "Roof" rat, Rattus rattus L.

Introduction

The behavioural taste threshold of laboratory rat for sweet, sour, salt and bitter substances; has ever been a subject of considerable interest. It shows their taste capacity, or otherwise the effectiveness of stimulants (sucrose, hydrochloric acid, sodium chloride and quinine chloride) at minimum concentrations (Koh & Teitelbaum, 1961). However, optimal discriminations are also influenced by physiological factors, as hunger and thirst (Campbell, 1958); which again have behavioural implications, that have also been investigated to the fullest (Koh & Teitelbaum, 1961).

Psycho-physical methods, wherein the rats are forced to taste solutions in order to avoid electric shock or alternatively have to be rewarded with food for making correct discriminations, are now universally used in tracking taste thresholds (Carr, 1952; Harriman & MacLeod, 1955; Campell, 1958). However, it was earlier investigated by preference method; that for sodium chloride in particular to demonstrate the effects of adrenalectomy (Richter, 1939; Carr, 1952). That the results obtained by the two methods may yet agree, has, however, been also proved (Koh & Teitelbaum, 1961). The preference method has thus still great utility.

Similar informations about wild rats, Rattus rattus L. & R. norvegicus Berkenhout, are, however, mostly lacking. Accordingly, preference taste thresholds of former for sweet, sour, bitter and salt solutions were investigated. The results are discussed here.

Material and Methods

Subjects: (i) The rats used in laboratory tests belonged to a wild-caught stock maintained on a laboratory rats diet and ad lib water. They were trapped at time of experiments; sexed, weighed and housed as bisexual colonies in seperate enclosures, 1 X 0.35 X 0.35 m. The same diet was continued.

Description of colonies is given in Table 1.

(ii) Free-living colonies of "roof" rats tried in the experiments, were residents of a flour-mill in University market, and of a farm-building located inside a ruined fortress near the campus (Fig.1). True estimates of rat numbers in either colony were never found, but it probably varied between 10 to 20 at both sites. Other rodent sps were, however, absent.

Preparation of Taste Solutions: Taste solutions were prepared from reagent quality chemicals.

10 g and 1 g of sucrose, citric acid, quinine

sulfate, and sodium chloride, were dissolved seperately in 1L of distilled water to prepare two standard solutions of each substance, of respectively 1% and 0.1% strength.

Dilutions were made thereof of both standard solutions by withdrawing 750 ml, 250 ml, 100 ml or 75 ml, 50 ml, 25 ml & 1 ml and making upto 1L. The first solution (10g/L) thus gave eight working solutions of respectively 0.75%, 0.5%, 0.25%, 0.1%, 0.075%, 0.05%, 0.025% & 0.01%. Similarly, eight working solutions were obtained from second standard solution (1g/L), viz. 0.0075%, 0.005%, 0.0025%, 0.001%, 0.00075%, 0.0005%, 0.00025%, 0.0001%.

Experimental Procedure: Concentration of taste solutions was decreased in 13 steps from 0.5% to 0.0001%. Each concentration was tested for one day.

Measured amounts of taste solution and filtered, unchlorinated tap water, were offered in seperate and marked glass dishes (diameter:22 cm). Residue was measured next day. Controls were run simultaneously in empty cages, or under wire-mesh cover at field sites, to measure loss of fluids due to evaporation. The difference was corrected for it, and taken to equal consumption.

Fresh solutions and tap water, were always offered. In case of spilling, tests were repeated.

Dishes were placed at corners at field stations. Position of dishes was alternated daily.

Analysis of Results: Equivalent intakes were taken to indicate failure to discriminate taste solutions or lack of preference. Intakes exceeding 50% of total were taken to show preference; and below this level rejection of taste solution. In any case, the data were used to find boundaries of taste thresholds. Molar concentration of taste solutions was also calculated.

Relative differences in consumption of taste solution and tap water, were compared by paired "t" tests (Bailey, 1959).

Results and Discussion

In laboratory colonies, quinine sulfate in concentrations greater than 0.0005%, citric acid above 0.01% and sodium chloride at strength exceeding 0.1% were rejected ($P<0.05$; Fig.2). Alternatively, more water was ingested by the rats. However, at concentrations respectively below 0.0005%, 0.001% and 0.1%, the taste solutions and water were consumed in equal amounts; or the differences were not very large (Fig.2). The two fluids were thus almost equally preferred. Sucrose was not preferred below 0.05% (Fig.2).

Unlike in the laboratory, however, rats in the free-living colonies were found to reject sodium chloride at 0.01% (Fig.3). Similarly, preference threshold for sucrose was also detected at lower concentration, 0.025%, than that observed in the laboratory (Fig.2,3). Quinine *sulfate and citric acid were, however, discriminated again to same strengths, 0.0005% & 0.01%, in free-living colonies (Fig.3).*

Taste thresholds thus differed in the two situations for sweet and salt solutions; but not for bitter and sour stimulants.

Of the four basic tastes apparently, only sweetness is associated with starchy foods that form the main diet of wild rodent species (Barnett, 1969, 1975). Conversely, bitter (quinine sulfate) taste indicates the presence of alkaloids, or foods toxic to them (Garcia et. al., 1974). Sour (citric acid) taste, when not indicating toxicity, is likely to be considered "novel"; while obviously salt solutions can not be favoured by them to any marked extent (Richter & Campbell, 1940). It would appear, therefore, that attraction to sweetness and rejection of the three other tastes, are also the responses normal to taste preferences of wild rodents.

As demonstrated for laboratory rats, however, such motivation to prefer certain tastes and avoid others, is by itself sufficient for attempts at very fine discriminations (Koh & Teitelbaum, 1961). This explains the close agreement often found between the results obtained by sophisticated psycho-physical methods, that create high degree of "motivation" in rats for tasting, and the *simpler preference method, that lacks any such effort. Presently it seems to indicate, however, that taste thresholds found for "roof" rats represent the "effectiveness" of each stimulating substance at minimum concentration; below which it's solutions must have been found as bland as water.*

Thus, the preference taste thresholds of "roof" rats for sucrose, citric acid and quinine sulfate (0.00073 M, 0.0005205 M, 0.00001189 M in free-living colonies; and 0.00182 M, 0.0005205 M, 0.00001189 M in laboratory; Figs.2,3) are finer than taste thresholds reported for laboratory rats (0.0099 M sucrose, 0.00046 M hydrochloric acid, 0.000012 M quinine chloride; Koh & Teitelbaum, 1961). Thresholds for sodium chloride (0.0169 M, 0.00169 M) are, however, comparatively much higher (Figs.2,3; 0.00074 M for laboratory rats; Koh & Teitelbaum, 1961). Probably, it indicates inter-specific differences; but varied influence of important determinants as hunger and thirst on our results can not be ruled out.

Factors as hunger and thirst may have also influenced the taste capacity of "roof" rats in laboratory and free-living colonies. Alternatively, the variations noticed may have occured due to differnece in "motivation" for tasting in rats living freely vis a vis rats restricted to cages. Thus, optimal discrimi-

nations are likely to be shown by former; for sweetness, and to some extent sodium chloride, have reinforcing value (Campbell, 1958; Koh & Teitelbaum, 1961). Contrary to search for favourable nutrients , the motivation to avoid toxic or novel tastes is, however, not impaired with confinement. Taste thresholds for bitter and sour substances are found, therefore, equal in both situations (Figs.2,3). Similar responses also characterise the self-selection of diet by wild rodents (Barnett, 1969; 1975; Barnett et. al., 1978).

__*Summary*__

Taste thresholds for sweet, sour, salt and bitter substances were obtained for wild rats, __Rattus__ __rattus__ L., by preference method. The rats were housed in bisexual colonies, and presented with taste solutions and alternative water in two seperate dishes. The same method was tried in comparing taste solutions on free-living colonies. Concentration of taste solutions was decreased in 13 steps from 0.5% to 0.0001%. Relative intakes at each strength were analysed to determine preference.

Optimal discriminations were noticed to 0.0005% 0.00001189 M) for quinine sulfate, 0.01% (0.0005205 M) citric acid, 0.1% (0.0169 M) for sodium chloride and 0.05% (0.00182 M) for sucrose in laboratory; and the same thresholds for quinine and citric acid in free-living

colonies, but not for sucrose, 0.025% (0.00073 M), and sodium chloride, 0.01% (0.00169 M), which were much lower. Difference in "motivation" for tasting was found responsible for variations observed in the two situations.

Table 1. Description of laboratory colonies used for the taste experiments.

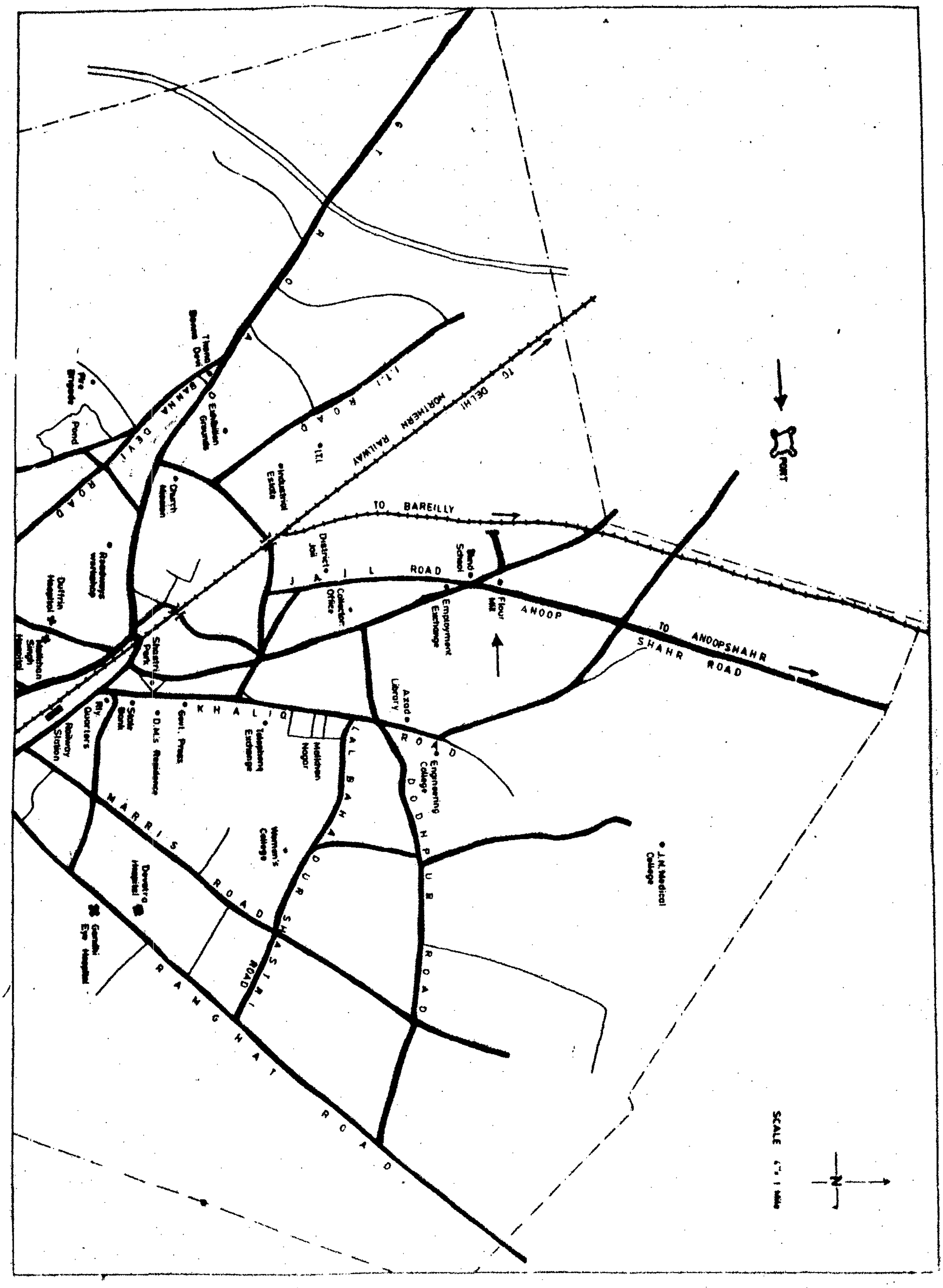
TABLE - 1

NO. Of Colony	No. of Rats		Body-weight (g + S.E.)	
	Male	Female	Mean	Range
1	2	2	121 ± 7.2	110 - 130
2	1	2	166 ±12.23	150 - 179
3	1	3	123.75±21.6	105 - 160
4	1	3	146.25±10.8	130 - 160

Figure 1 : *The figure shows the location of study or experimental areas. The flour mill is situated on the Anoopshahr Road, not far from the department in the same quardere - angle. The fort is in the outlying area, and has more or less a rural background.*

Figure 2.

The tasting ability of roof rats, is shown to vary in different areas in the laboratory. The relative intake of taste solution and water changes in the threshold range.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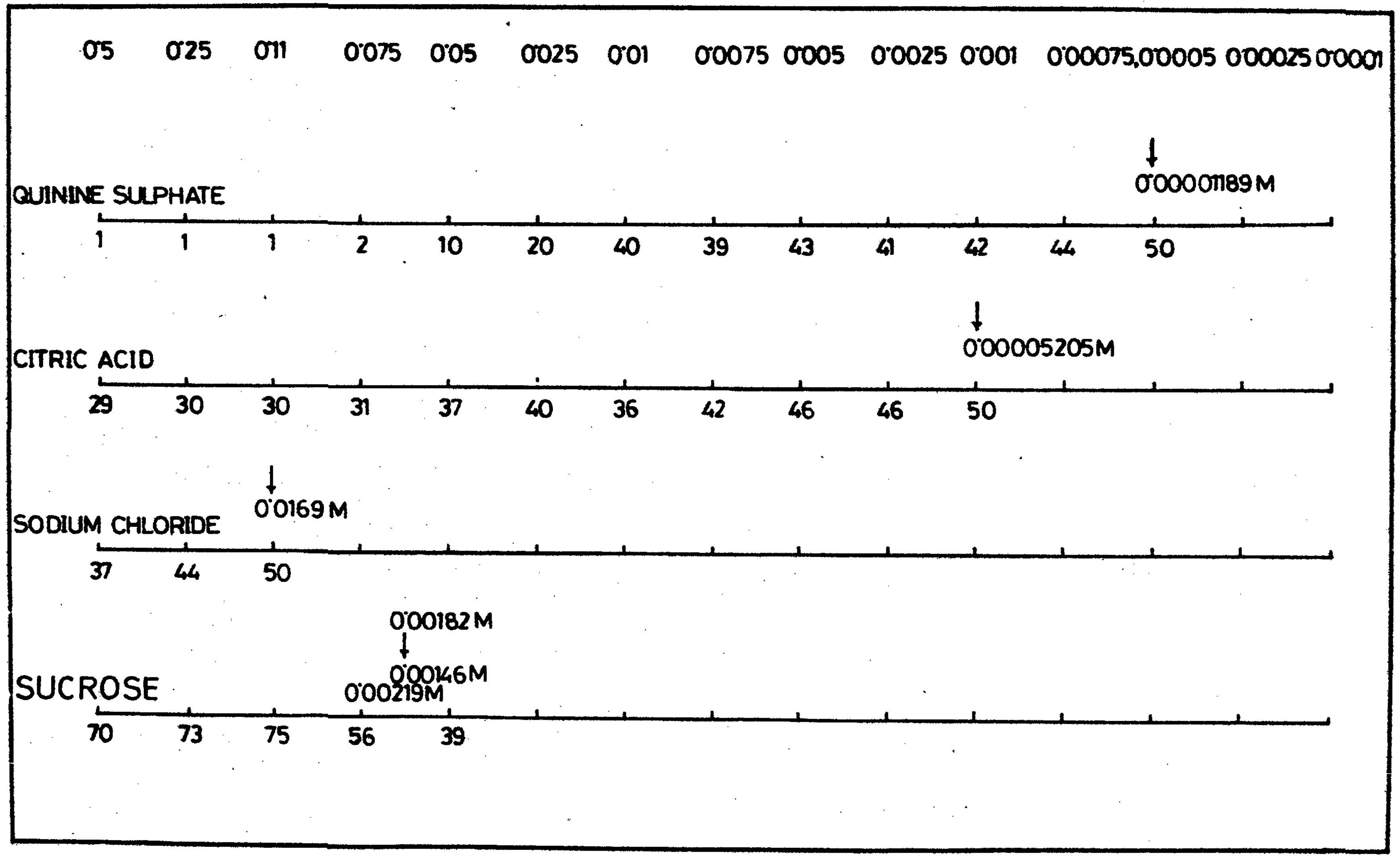
NORTHERN RAILWAY
TO DELHI
TO BAREILLY
JAIL ROAD
ANOOP SHAHR ROAD
TO ANOOPSHAHR
KHALIQ
LAL BAHADUR SHASTRI ROAD
MARRIS ROAD
RAMGHAT ROAD
DODHPUR ROAD
BANNA DEVI ROAD
FORT
Fire Brigade
Pond
Exhibition Grounds
I.T.I.
Industrial Estate
Church Mission
Roadways workshop
Dufferin Hospital
Malkhan Singh Hospital
District Jail
Collector Office
Band School
Employment Exchange
Flour Mill
Shastri Park
Azad Library
Rly. Quarters
Railway Station
State Bank
D.M.s Residence
Govt. Press
Telephone Exchange
Women's College
Engineering College
J.N. Medical College
District Hospital
Gandhi Eye Hospital
SCALE 4" = 1 Mile
N

Fig.1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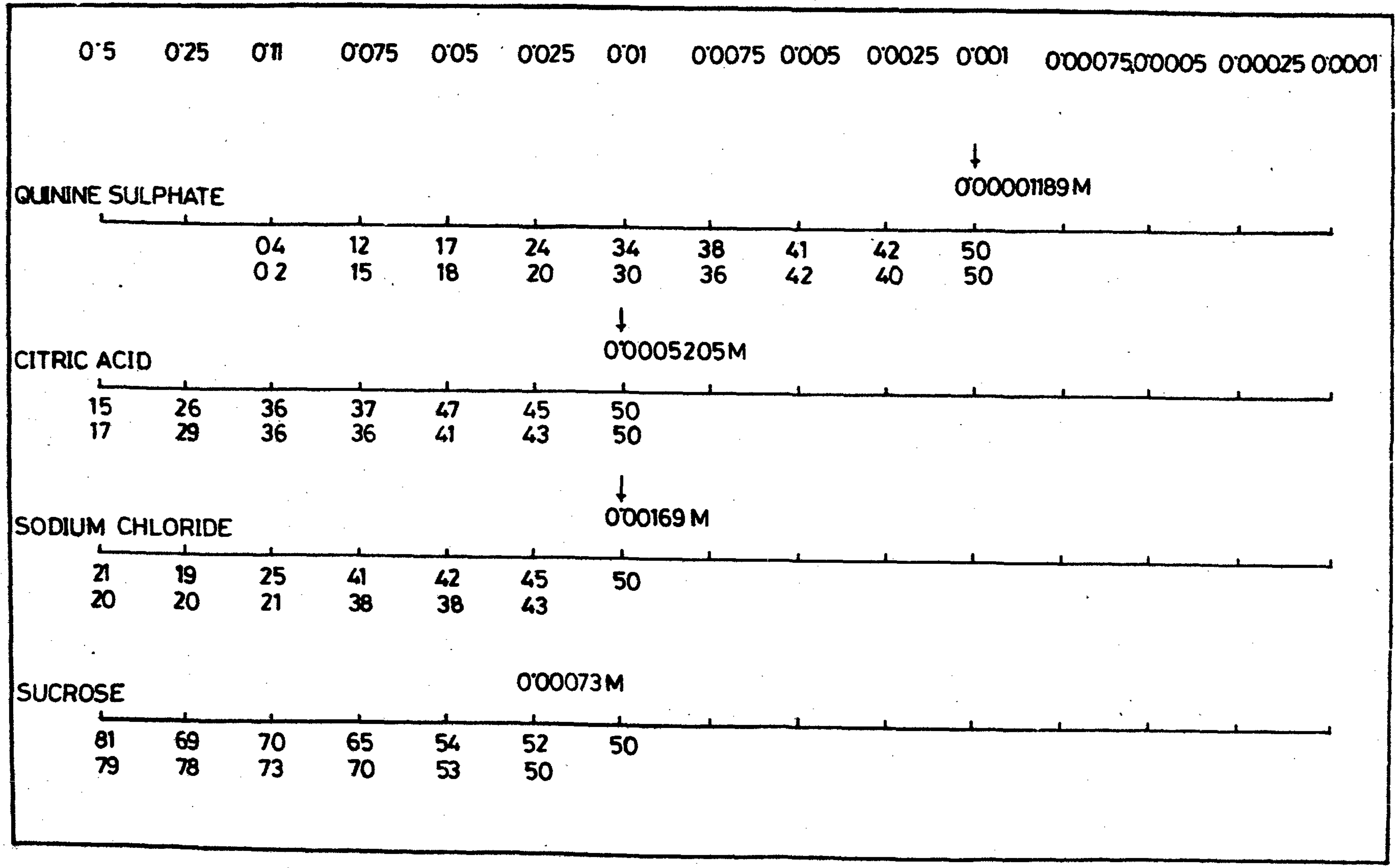
QUININE SULPHATE
0'00001189 M
1 1 1 2 10 20 40 39 43 41 42 44 50
CITRIC ACID
0'00005205M
29 30 30 31 37 40 36 42 46 46 50
SODIUM CHLORIDE
0'0169 M
37 44 50
SUCROSE
0'00182 M
0'00146M
0'00219M
70 73 75 56 39

Fig. 2

Figure 3.

The tasting ability of free living rats is shown to be greater for sodium chloride and sucrose than that observed in the laboratory. The other two substances, quinine sulfate and citric acid, are discriminated down to the same strengths.



0'5 0'25 0'11 0'075 0'05 0'025 0'01 0'0075 0'005 0'0025 0'001 0'00075 0'0005 0'00025 0'0001
QUININE SULPHATE
0'00001189 M
04 12 17 24 34 38 41 42 50
0 2 15 18 20 30 36 42 40 50
CITRIC ACID
0'0005205 M
15 26 36 37 47 45 50
17 29 36 36 41 43 50
SODIUM CHLORIDE
0'00169 M
21 19 25 41 42 45 50
20 20 21 38 38 43
SUCROSE
0'00073 M
81 69 70 65 54 52 50
79 78 73 70 53 50

Fig. 3

Consummatory Intakes of Common Sugars by "Roof" rat, Rattus rattus L.

Introduction

From among sweet foods, sugars are much preferred by laboratory rats (Richter & Campbell, 1940). The choice varies, however, over a wide range of concentrations (McLeary, 1953). Of this, consumption increases monotonically with concentration, or strength of sweet taste perceived, in the hypotonic range (Young & Madeson, 1963); while reversal of choice occurs across the hypotonic range (McLeary, 1953; Barnett, 1975). More water than sugar solution is ingested at aversion point (McLeary, 1953; Shuford, 1958).

It appear thus that consummatory intakes of sugars in laboratory rats are regulated both by "oral", or taste factors, and "post-ingestive" factors (McLeary, 1953; Shuford, 1958). Accordingly, an addition between the two determines choice, particularly at higher concentrations. Obviously, this has behavioural implications (Hagstrom & Pfaffmann, 1958); which have also been analysed by several authors (Booth et al., 1972).

"Roof" rat, Rattus rattus L., also show great liking for sweet foods (Khan, 1974). However, changes in it's sugar preferences corresponding to concentration, have not been examined. The results of experiments designed to examine it, are discussed here.

<u>Material and Methods</u>

Subjects of wild-caught stock, were sexed, weighed and grouped into bisexual colonies of 5 to 7 rats. Juveniles ($<$80g) and pregnant females, were excluded. The rats were fed on wheat, cabbage; water was given <u>ad lib</u>.

Description of colonies is given in Table 2.

<u>Preparation of Sugar Solutions</u>: Sugar solutions were prepared 24 hrs before presentation by dissolving the desired quantity of laboratory grade sugars, except jaggery, in 1L or fractions thereof of distilled water. Jaggery was purchased from the local market. Strength of solutions is reported in % w/v.

<u>Experimental Procedure</u>: Measured amounts of sucrose, jaggery, glucose, maltose, fructose or lactose, and the alternative water; were offered in seperate dishes (diameter : 22 cm). Position of dishes was alternated daily. Controls were run simultaneously in empty cages. Residue was measured next day. Intake was calculated by difference and adjusted for loss in controls.

The strength of solutions was increased over log scale, by 0.3 units in 1-10% range (1.209%, 2.4109%, 4.812%, 9.6%) and 0.5 units above it (12.59%, 14.13%, 15.85%, 17.8%, 20%, 22.39%, 25.12%, 28.20%). The solutions were offered in ascending order, for one day each to the same colony. Intake of each sugar in the range 1-28.2%, was thus measured for 11 to 12 days. Tests were also terminated at 25.12%. When the fluids were spilled, observations were repeated.

__Analysis of Results:__ Actual amounts of sugars ingested at each concentration were also calculated. The results are expressed in g consumption/100g body-weight.

Intakes exceeding 50% of total fluid consumption were taken as evidence of preference. The significance of preferences was found by paired "t" tests (Bailey, 1959).

The relationship between observed (x) and expected consumption (y), both in volume and solute-weight terms, as defined by equation $y = a + b^{2} + c^{2}$, *was analysed by "Fitten Programme" in a Fortran IBM 1130 Computer.*

__Results__

Results are summarised in Tables 3 & 4.

__Loss of Fluids:__ Wastage of test solutions due to entry of rats into dishes, was observed on some occasions. Such losses could not be, however, measured. They were, however, negligible.

<u>Volumetric Intakes:</u> Of total fluid consumption at lower ranges, sugar consumption averaged about 85% (Fig.4) excepting of course lactose (Table 3). Water was often ignored as with maltose (Table 3). However, such "marked" preference was shown over a wider range of concentrations for glucose and sucrose, 1.209 to 17.80%, than for maltose, 1.209 to 15.85%, jaggery, 1.209 to 14.13%, or fructose, 1.209 to 12.59% (Table 3). The preferred ranges of concentration, differed considerably.

Unlike it, sugar consumption was reduced with further rise of concentrations, or at still higher ranges; while intake of water was increased simultaneously by the rats (Table 3). However, consumption of fluids, sugar solution and water, was equalised by them gradually before the choice was reversed; or when more water than sugar solution was ingested (Table 3). Aversion was, however, shown at variable concentrations; for glucose and sucrose at 28.2 %, jaggery 25.12%, maltose 20% and for fructose at 20% (Table 3 ; Fig.4)

Lactose was only slightly preferred by rats at 14.13% (Table 3).

Solute-weight Ingested: The actual amounts of sugars ingested at lower concentrations, <5%, obviously amounted to very little (Table 4). Maximum appetite was shown by rats for glucose, 4.913g at 15.85%, followed by sucrose, 4.574g at 17.8%, fructose, 4.316g at 12.59%, maltose, 4.044g at 15.85%, jaggery, 3.482g at 14.13% and lactose, 2.14g at 14.13% (Table 4). Glucose was thus consumed in largest amount; though the amounts ingested of other sugars, except jaggery and lactose, were not very different. Optimum choice was also observed at different concentrations.

Changes in Preference Function with Concentration: The strength of sugar solutions presented to rats, was increased by equivalent degree, or log units. An orderly difference in choice on both the ascending and descending limbs of preference function was, therefore, expected.

Any increase in sugar preference was, however, not obvious from volumetric intakes; though decline in choice at higher ranges, was clear from such data, (Table 3). Unlike it, equivalent differences did occur in solute-weight terms; changes of which thus approached a bell-like form when plotted, or in scatter diagram(Fig. 5).

In either case, however, no significant relationship was indicated between expected and observed consumptions at different concentrations ($P > 0.05$).

Discussion

The laboratory rats show optimum choice for sugars, both in volume and solute-weight terms, at about 10% strength (Young & Madeson, 1963). This figure is thought to represent the compromise between (1) oral factors, or taste, which facilitate acceptance, so that intake increases monotonically with concentration for sucrose at least, (2) and "post-ingestive" factors, or set of factors, which inhibit acceptance, and tend to become more intense with increasing hypertonicity (McCleary, 1953; Shuford, 1958). However, as an exact integration is not always possible post-ingestive regulation often fails to overpower the effects of increasing sweetness, or choice (Booth et al., 1972).

Similar effects of sweetness, with increase in concentrations made on consecutive days, facilitated perhaps greater acceptance, of sugars in our experiments. Optimum consumption thus occured over a wide range of concentrations, which was inhibited only by very high degrees of hypertonicity (Table 3, 4). Presence of water further ameliorated it's effects (Shuford, 1958). This accounts thus for the discrepency noted between consumption and concentration, in volume and solute-weight terms, on both increasing and declining limbs of preference function. It is clear, however, that consumatory intake *of sugars in "roof" rat, with alternative water, is predominantly regulated by taste factors.*

However, as of taste, common sugars are not equally sweet; but of them, fructose is the sweetest (Bell et al., 1965). Maltose has, however, the most effective taste (Hagstrom & Pfaffmann, 1959). Confirming to this thus, fructose is declined by rats at much lower concentration than other sugars (Table 3). Maltose also becomes aversive at about the same strength; below which, however, it is always more preferred, with water often ignored in it's presence (Table 3). Compared to glucose and sucrose similarly, jaggery is perhaps sweeter; though it contains mostly the latter. Perhaps some other sugars, specially fructose, are also left in it from the original cane-juice. As according to relative sweetness thus, aversion for glucose and sucrose is reached at higher concentration than jaggery (Table 3). However, lactose has apparently the weakest taste; though some nutritional factors are also the cause of it's avoidance (Richter & Campbell, 1940).

Common sugars are thus preferred by "roof" rats over variable range of concentrations because of differences in their sweetness. Sweetness seems to follow in the order - fructose > maltose > jaggery > glucose > sucrose lactose.

SUMMARY

Consummatory intakes of sugars by 'roof' rats varied over the wide range of concentrations (1.029 to 28.2% w/v) that they were presented with alternative water. But "marked" preference was shown to sucrose and glucose over a larger range (1.029 to 17.8%) than to either maltose (1.029 to 15.85%), jaggery (1.029 to 14.13%) or fructose (1.209 to 12.59%).

It was predominantly regulated by oral factors or taste; while post-ingestive effects appeared to effect intake only at high concentrations.

Table 2. *The table shows the number, and sex of rats in each colony. Mean body-weight of the colonies is also given, with standard errors of the mean ($\pm$ S.E.).*

TABLE - 2

No. of Colony	No. of Rats		Body-weight (g ± S.E.)	
	Male	Female	Mean	Range
1	1	3	113.25 ± 3.50	105 - 120
2	2	1	110.0 ± 12.39	90 - 140
3	2	1	118.33 ± 7.35	105 - 130
4	1	3	123.75 ± 13.45	105 - 160
5	1	3	123.00 ± 12.45	107 - 160
6	2	1	167.33 ± 16.91	82 - 140

Table 3. The amount of sugar solution and water consumed in the colonies, at different concentrations.

TABLE - 3

Test No.	Rat Colony No.	Choice	Consumption in ml at % concentration of											
			1.~~0~~23	2.43	4.86	9.6	12.59	14.13	15.85	17.78	19.95	22.39	25.12	28.2
1	5	Sucrose	100	95	102	111	122	134	134	128	78	74	64	39
		Water	6	6	4	4	8	2	6	16	22	36	50	57
2	4	Jaggery	108	114	115	117	136	122	76	62	50	48	36	-
		Water	8	11	6	1	10	10	26	48	38	40	52	-
3	6	Glucose	60	56	62	74	90	102	100	88	52	46	48	39
		Water	6	10	4	6	2	2	10	14	32	38	46	53
4	1	Maltose	86	78	74	92	114	130	116	92	30	26	16	-
		Water	0	20	8	4	0	0	8	34	50	54	56	-
5	3	Fructose	108	111	120	117	122	80	48	46	26	24	24	-
		Water	16	6	9	0	8	18	26	46	34	40	54	-
6	2	Lactose	34	42	44	24	42	50	22	26	22	12	6	-
		Water	58	46	40	56	42	44	56	68	66	66	76	-

Table 4. The actual solute weight ingested during the drinking of sugar solutions over a wide range of concentrations. Maximum amounts are ingested at strength ranging from 9-17%.

TABLE - 4

% Consumption of solution	Actual sugar consumption, g/100 g body-weight					
	Sucrose	Jaggery	Glucose	Maltose	Fructose	Lactose
1.023	0.205	0.264	0.19	0.194	0.31	0.105
2.43	0.459	0.559	0.421	0.416	0.757	0.309
4.86	0.996	1.128	0.934	0.791	1.638	0.647
9.6	2.14	2.268	2.202	1.943	3.156	0.698
12.59	3.087	3.458	3.512	3.157	4.316	1.602
14.13	3.805	3.482	4.467	4.041	3.176	2.14
15.85	4.269	2.433	4.913	4.044	2.137	1.056
17.78	4.574	2.226	4.85	3.598	2.298	1.40
19.95	3.127	2.014	3.215	1.316	1.457	1.329
22.39	3.30	2.170	3.192	1.280	1.509	0.814
25.12	3.231	1.826	3.737	0.884	1.694	0.456
28.2	2.210	-	3.409	-	-	-

Figure 4.

The figure shows the percent consumption of sugar solutions compare to ordinary tap water. Large volume are ingested upto very high concentrations (S - Sucrose, G - glucose, J - jaggery, F - fructose, M - maltose, L - lactose).

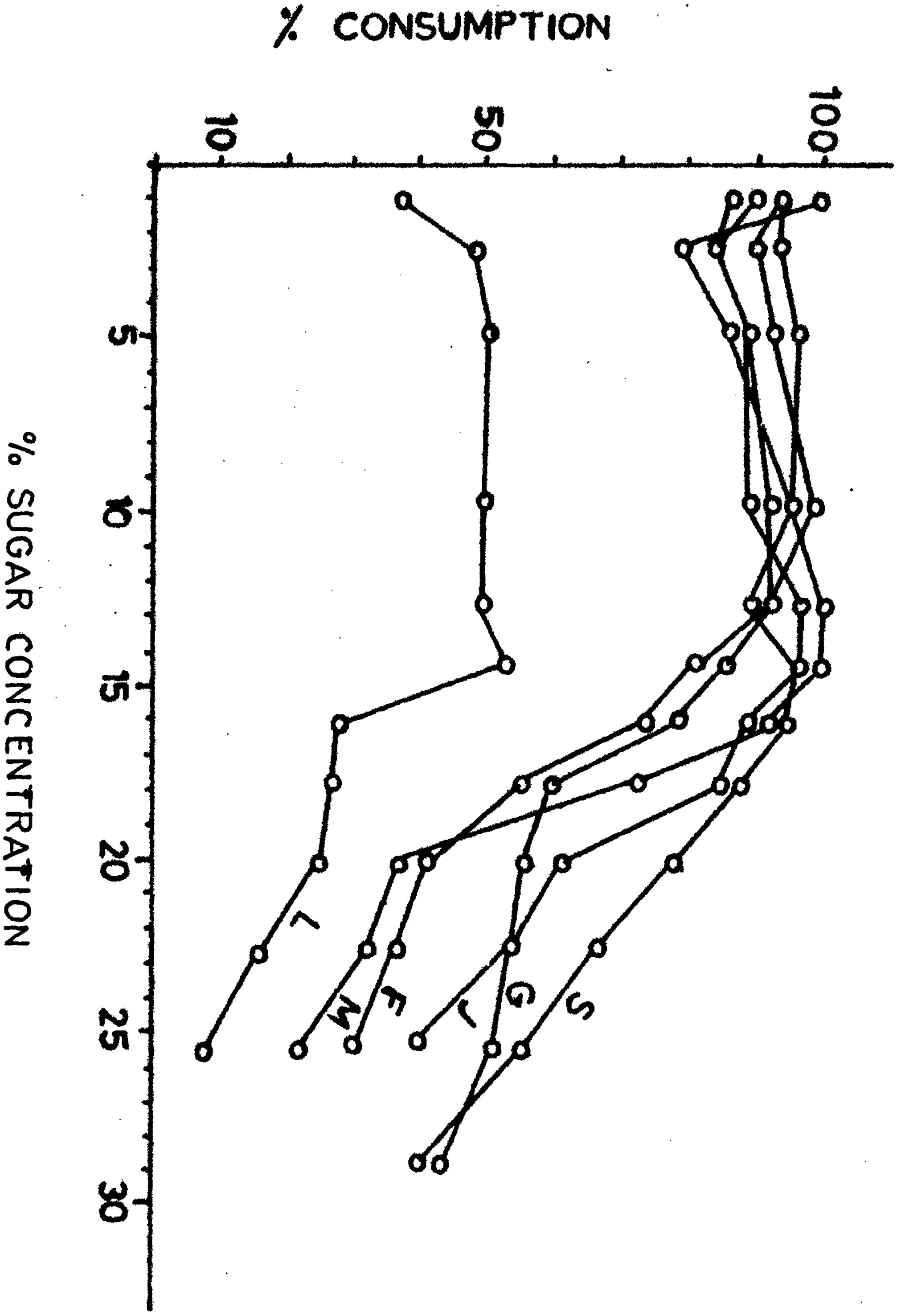
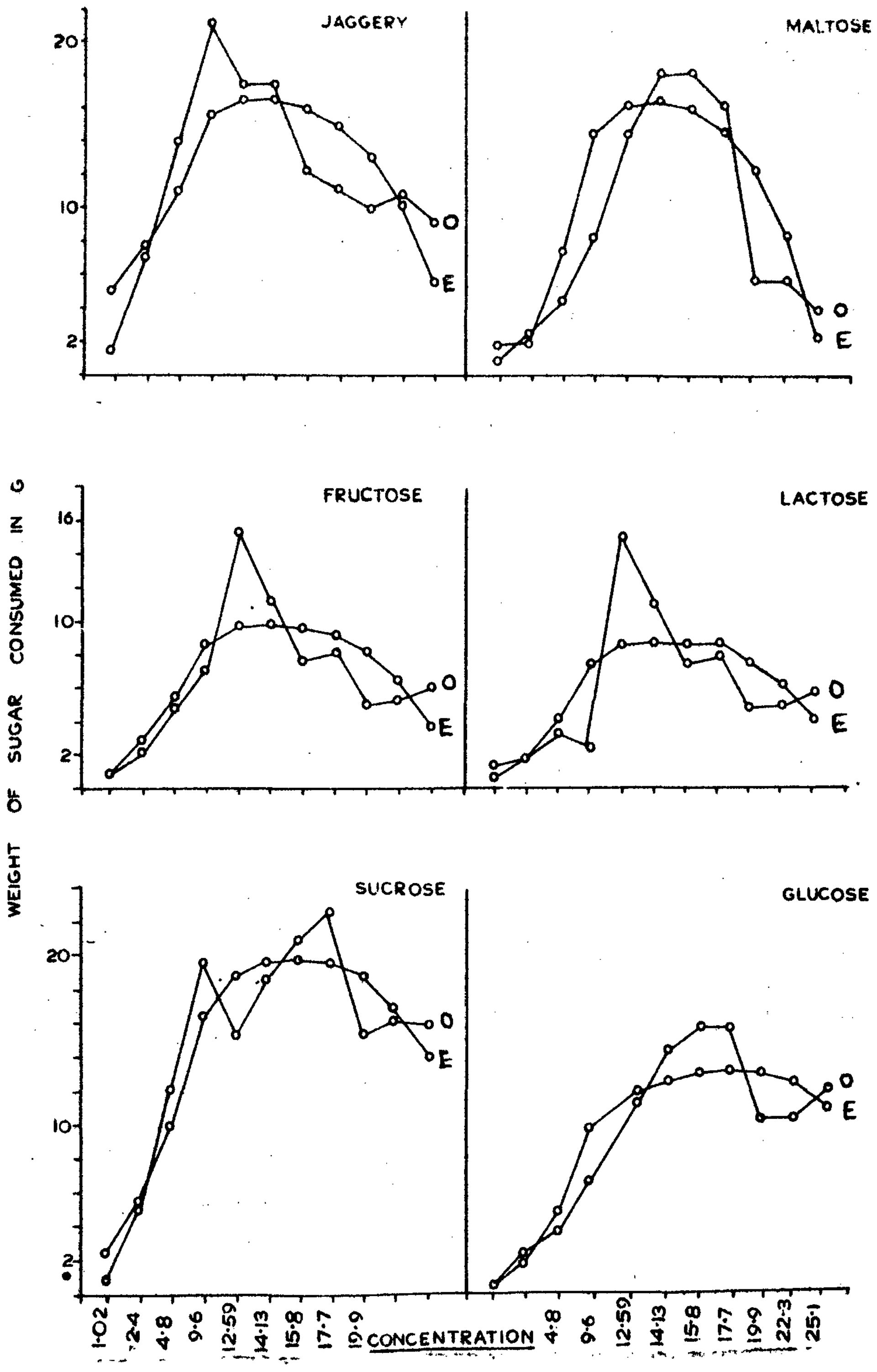

% CONSUMPTION
100
50
10
5
10
15
20
25
30
% SUGAR CONCENTRATION
L
M
F
J
G
S

Fig. 4

Figure 5.

The amount of sugar in gms. actually consumed by rats at different concentrations of sugar solutions offered. Both expected and observed consumption is plotted, the former assuming bell shape function (O - observed, E - expected).



JAGGERY
MALTOSE
FRUCTOSE
LACTOSE
SUCROSE
GLUCOSE
WEIGHT OF SUGAR CONSUMED IN G
CONCENTRATION
O
E
20
10
2
16
1·02
2·4
4·8
9·6
12·59
14·13
15·8
17·7
19·9
22·3
25·1

Fig. 5

SUGAR PREFERENCES OF "BLACK RATS", RATTUS RATTUS L.

INTRODUCTION

Selection of sweet foods has adaptive value (Garcia, Hankins & Rusiniak 1974), and it may be quite general among mammals. However, the preferences from among sweet foods, such as sugars, is adequately known only for the laboratory rat Rattus norvegicus (Hagstrom & Pfaffmann, 1959). Wild rats, R. norvegicus and R. rattus, prefer foods sweetened with sucrose or even saccharin (Barnett & Spencer, 1953; Khan, 1974); but nothing is known about their response to other common sugars. The selection of "black rats", R. rattus, from among sucrose, jaggery (Indian shakkar, coarse brown and chemically the same as cane sugar; Everyman's Encyclopedia, 1959), glucose, fructose and lactose, was studied by presenting solutions to both captive and free living colonies.

MATERIAL AND METHODS

Laboratory Colonies: "Black rats", Rattus rattus rufescens, (dorsally brown and ventrally off-white) were trapped as adults from the flour mills in Aligarh city. Animals were sexed, weighed and housed in bisexual groups in galvanized wire-mesh cages of size 1.12 X 1.0 X 0.32 m. Pregnant females were excluded. None of the females became pregnant during the experiments. The rats received daily a surplus of wheat flour, with cabbage once a week and buffalo's liver fortnightly. Presumably they were eating wheat flour before capture. They drank water from two glass dishes (diameter 12 cm), each holding about 500 ml of water without any danger of spilling. The same dishes contained test solutions when the experiment started. Six days were allowed to each colony for adjustment in the laboratory. A colony was used only for one test, and each test lasted for not less than 5 days.

Free Living Colonies: (i) A colony of "black rats" infesting a farm building, inside an 18th century Maratha Fortress, was used for field trials. The building comp-rised of two narrow rooms (2.42 X 2.42, 2.42 X 8.48 m) by the side of approach road, two sizable rooms (4.84 X 5.15, 4.84 X 5.15 m) in the middle, and a row of smaller rooms (3.93 X 2.42, 6.66 X 2.42 m), some interconnected in the rear (Fig.6).

Repeated trappings showed the presence of "black rats" only. When the experiments started, in September 1975, most rats were living in one of the big middle rooms packed with a variety of farm implements, sacks of barley *and hay. Observation revealed the presence of 13-20 rats on most nights. In February 1976, barley, along with fresh supplies, was transferred to one of the rooms in the rear. Within a few days, all the rats had moved into it, and experiments were continued there.*

Both the rooms were deeply tunneled, particularly in the corners. At both places water dishes were placed on the floor, close to the wall bearing the largest number of holes. Sugar solutions replaced water when the tests started. Only water was given between the tests.

(ii) Another colony of "black rats" infesting a grain-store (5.45X3.03 m) in the University market, was tried similarly for some tests. It comprised of a single room packed with canisters of salt, spices, pulses and sacks of grains. The rats had free access to whatever was not packed in tins, mostly grains. The size of the population was not known, but the number was smaller than in the colony at fort.

Experimental Procedure: Reagent quality glucose, fructose, lactose and sucrose were used throughout. Jaggery was purchased from the market. The solutions (5% w/v) were prepared in tap water. The solutions were warmed to 80°C (Pfaffmann et al., 1954), and allowed to stand another two hours before use. Fresh solutions were prepared daily.

Two solutions were offered at a time. 500 ml of solution was given in each dish. The residue was measured at the same time next day. Daily intake was measured to nearest 5 ml and a correction was made for loss due to evaporation.

At the farm building and the store, test solutions were each given in two dishes, either facing the wall or holes, or in the rear (Fig.7).

At field stations glucose was first compared, in successive tests, with fructose, lactose, jaggery and sucrose. In the next series of tests, fructose was similarly given with three other sugars. Lactose was then compared to jaggery, and then to sucrose. The choice consisted of sucrose and glucose in the last test.

Occasionally soil was kicked into the dishes; such findings were discarded. Spillage was checked by placing the dishes in porcelain containers (46 X 32 X 6cm).

In the cages the position of test solutions was alternated daily, and bias for the contents of a dish in a particular position was never observed. At fort also the positions were interchanged (Fig.7), and solution of any one kind was never available in the same row or column.

Observations on Behaviour: Removal of water at the fort, even for a day, seemed to make the rats very thirsty. They came out to drink whenever the dishes were replaced. An observer (E) then watched them, recording the number of visits and the attempts, if any, to spill the test solutions. Laboratory colonies were similarly watched.

Statistical Analysis: Differences in sugar consumption were analysed by Students' "t" test (Bailey, 1959). Intakes recorded from each dish at the fort, were compared by 2 X 2 contingency tables (Bailey, 1959), without Sheppard's correction.

RESULTS

Loss of test fluids: Rats in laboratory colonies wasted little of the fluids. At fort, however, rats occasionally ran across the dishes or climbed inside when pushed by conspecifics. Such losses could not, however, be measured.

Effect of place preference: In some tests at fort, e.g. when sugar was given with water, the rats drank more from the dishes facing the holes than from those at the rear. A similar association of position and consumption also existed when sugars were given (Table 5). Of the sugar preferred, a higher amount was usually drunk from *dish I, and of the less preferred sugar from dish 2 (Table 5). The obverse was true, however, when jaggery was offered with either fructose or lactose. In any case, the solutions in none of the four dishes were ever ignored. The contents were sampled freely, though particular attention was then directed to dishes containing the more attractive alternatives.*

Sampling Behaviour: The rats tended to gather round one dish, and drank slowly with intermittent pauses and rapid sniffing. Then some rats left to taste the contents of other dishes, but returned quickly. This behaviour was repeated by all the rats. On one occassion thus, we observed the rats drinking lactose from dish I for about an hour before finally dispersing to the dishes containing sucrose, the better choice. The lactose dish was, however, visited repeatedly, but apparently not much was drunk on each visit.

However, rats in laboratory colonies immediately accepted a novel sugar when a familiar alternative was simultaneously present, or at least consumed it in large amounts. But the fort rats always avoided a novel sugar or when the same sugar was given after a gap of several days. The avoidance persisted for a day or more before the novel choice, if superior, was accepted (Fig.10).

Sugar Preferences of Free-living Colonies: The rats at the fort, as also in the store clearly preferred sucrose to glucose ($p < 0.05$). It was consumed in greater amounts on all occasions except in two tests, when more of fructose and jaggery were initially consumed (Fig.8). In both tests, however, the rats had already been receiving them in some other combination.

Jaggery was also preferred to glucose (Fig.9), fructose and lactose (Table 5). There were, however, some initial changes in preference when it was tested with glucose. Lactose was almost ignored by the end of the test (Table 5).

The rats selected glucose in preference over fructose or lactose ($p < 0.05$, Table 5), and fructose over lactose (Table 1). In all tests, including those with lactose, the inferior alternatives were consumed in considerable amounts. When offered with water, lactose, like other sugars, was mainly consumed (Fig.10). Any aversion for lactose, as evident in laboratory tests (Table 6), was not observed.

Equivocal choices were not observed on any occasion. The sugars tested were clearly preferred in the order sucrose > jaggery > glucose > fructose > lactose (Table 5).

Sugar Preferences of Laboratory Colonies:

In some colonies glucose was greatly favoured over sucrose (Table 6). It was, however, only marginally preferred in one colony (Table 6, Fig.11). Glucose was also selected when compared to fructose ($P < 0.05$; Table 6), though the choice was equivocal on some days. It was, however, consistently preferred to jaggery and lactose ($p < 0.05$; Table 6).

Fructose was preferred to lactose, and also initially to sucrose or jaggery (Table 6). But in the latter tests, the choice soon reversed and did not change subsequently. Sucrose was clearly preferred to jaggery ($p < 0.05$), and both to lactose (Table 6).

The rats in the laboratory selected the sugars in the order glucose > sucrose > jaggery > fructose > lactose. The response to glucose, when compared to sucrose, was rather variable. In other tests, excepting those with lactose, the inferior alternatives were also consumed in significant amounts.

Consumption of lactose, whenever offered, declined with time. Water was drunk equally to it, and in some colonies even in slightly large amounts (Table 6).

<u>Regulation of Fluid Intake</u>: Regulation of fluid intake was not followed, as the experiments were conducted over a wide range of temperature and humidity. Preliminary trials, however, showed that in the range 18° to $24^{\circ}C$, about 40 ml water/100 g body weight was drunk daily.

However, no attempt was made to translate total consumption of fluids at the fort into number of rats.

Discussion

The fort rats, on leaving the burrows, immediately visited the dishes facing their exit points. Larger intakes of test solutions from both or either of these dishes was, therefore, expected (Table 5). It was, however, observed only when the choice was limited to one sugar solution, the alternative being water; when sugars were compared, the contents of all the dishes were sampled freely. That shows their tendency to vary the diet, a behaviour which has great survival value (Barnett, 1969).

The rats at fort and also at the store, showed hesitation in accepting a novel sugar. This behaviour, of "adaptive feeding", was not clearly shown by the rats of the laboratory colonies. Nothing seems to account for this discrepancy; more investigations are apparently needed to clarify it.

The sugars tested vary in their effects on water intake. Sucrose provokes thirst while glucose does not (Beck, 1967). Such effects of the sugars offered, may have also contributed to variations in total consumption of solutions, besides those related to air temperature *and humidity. In field tests, it also reflected the variable number of rats visiting the dishes.*

The response of laboratory R. norvegicus to sugars, is influenced by (i) their taste effectiveness and (ii) their post-ingestive consequences (Guttman, 1954; Richter & Campbell, 1940). In behavioural tests designed to compare sugars on the basis of taste effectiveness, sucrose is preferred to glucose. However, glucose is favoured over sucrose in situations where the two are freely available. Beneficial effects of ingesting glucose then influence consummatory behaviour, and the greater effect of sucrose's taste is masked (Hagstrom & Pfaffmann, 1959).

The sugars were compared by the same method on rats living in two different situations. When restricted to small cages the "black rats", R. rattus, preferred the sugars in order glucose > sucrose > jaggery > fructose > lactose. The fort rats, however, selected the test sugars in the order sucrose > jaggery > glucose > fructose > lactose (Table 5 and 6). Apparently, post-ingestive consequences influence the consummatory behaviour of rats in laboratory colonies while taste sensivity acts alone in case of "black rats" living in wild.

Rejection of lactose in laboratory trials shows that its effects are hardly beneficial (Richter & Campbell, 1940). No such aversion is, however, detected in tests conducted at fort (Table 5). It may be surmized that some natural fats, known to help its assimilation (Richter & Campbell, 1940), might have been available at fort. This is unlikely as the rats there had only barley to eat, which they duly followed wherever it was moved. Only a few could venture outside because of many snakes, monitor lizards and feral cats around. Evidently its sweet taste, even though weak, attracted the rats. This further demonstrates the influence that taste exerts on consumption in natural conditions.

For the reason, the "black rats" living at fort displayed strong adaptive feeding response, whereas those confined to cages were relatively insensitive.

SUMMARY

Preferences of "black rats", Rattus rattus L., for sucrose, jaggery, glucose, fructose and lactose, based on relative intakes of 5% solutions in two-choice test situations, are described. In laboratory colonies, the sugars are found to have been preferred in the order glucose > sucrose > jaggery > fructose > lactose. However, a colony of "black rats" infesting a farm building, selected them in the order sucrose > jaggery > glucose > fructose > lactose. Apparently, relative sweetness of sugars largely influenced the consummatory behaviour of free-living rats and post-ingestive consequences of those restricted to cages.

Table 5. Mean daily consumption of the field colonies presented with any two of the five sugars

TABLE - 5

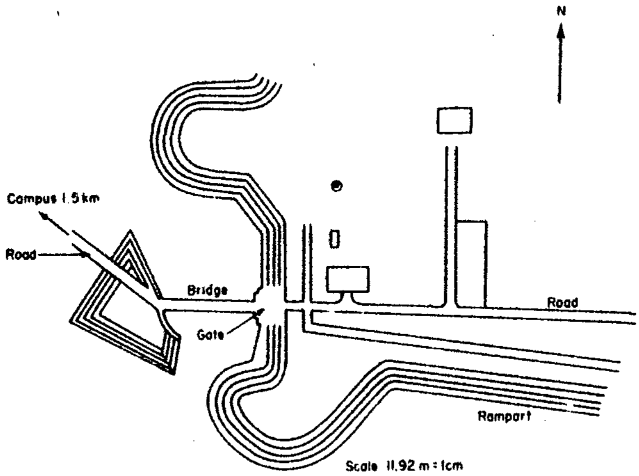
Test no.	Length of test (days)	Choice	Mean daily consumption ml/day ± S.E. Dish 1	Dish 2
1	5	Glucose/Fructose	337.0±43.0/ 85.0±27.8	378.0±41.3/130.0±48.2
2	5	Glucose/Fructose	106.0±24.1/ 86.0±12.0	105.0±10.8/ 99.0±16.5
3	6	Glucose/Lactose	133.1± 3.6/ 83.3± 5.1	89.1± 5.0/ 74.1± 2.3
4	10	Glucose/Jaggery	129.5±31.2/184.5±27.1	116.5±36.2/232.5±31.1
5	6	Glucose/Sucrose	72.5± 5.3/194.0±17.3	108.0±12.8/199.0±10.3
6	7 Store	Glucose/Sucrose	57.0±11.4/210.0±20.7	82.0±13.7/197.0±25.5
7	4	Glucose/Water	432.2±39.0/ 32.5± 7.7	450.0±11.6/ 26.2± 2.6
8	11	Fructose/Lactose	173.3±18.8/ 72.5± 7.6	140.8±25.2/ 62.0±12.8
9	12	Fructose/Jaggery	114.0±13.7/371.0±20.9	58.0± 6.1/387.0±25.9
10	7	Fructose/Sucrose		170.1±12.8/413.7±29.2
11	13	Fructose/Water	307.0±60.0/ 57.0±18.2	272.0±32.7/ 73.0±34.5
12	14	Lactose/Jaggery	27.0± 5.4/198.0±13.2	118.0±11.4/263.0±17.2
13	6	Lactose/Sucrose		122.16±14.5/400.5±19.5
14	15	Lactose/Water	218.8±18.0/ 79.0± 7.1	213.0±33.4/100.0±14.0
15	5	Jaggery/Sucrose	62.0±16.0/257.0±10.0	115.0±16.0/233.0±22.6
16	4	Sucrose/Water	388.7±63.5/ 22.5± 2.5	277.5±42.0/ 1125± 1.2

Table 6. The choice of laboratory colonies of black rats for sugars, offered two at a time

TABLE - 6

Test no.	No. of rats in colony	Length of test days	Mean body wt(g) ± S.E.	Choice	Mean daily consumption ml/day ± S.E.	Total Consumption ml/100 g body wt/day
1	4	6	188.25± 8.25	Glucose/Sucrose	214.33±23. 2/101.66±16.0	42.0
	4	22	166.0 ±23.2	Glucose/Sucrose	165.6 ± 0.82/134.5 ± 1.54	62.5
2	4	5	166 ± 6.8	Glucose/Jaggery	204.8 ±47. 8/ 66.0 ± 7.0	40.0
3	2	8	168. 5± 9.2	Glucose/Fructose	91.25±13. 6/ 60.37± 9.1	44.0
4	5	5	146. 4± 7.7	Glucose/Lactose	365.5 ±14. 3/ 65.0 ± 7.6	54.8
5	3	6	161. 3± 5.0	Glucose/Water	168.5 ±15. 2/ 30.0 ± 5.0	41.0
6	3	5	151. 0± 2.7	Sucrose/Jaggery	168.0 ± 8.4 / 75.2 ±17.6	55.0
7	3	9	180. 2± 5.2	Sucrose/Fructose	178.0 ±13. 9/138.0 ±10.3	55.0
8	3	5	161. 3± 5.0	Sucrose/Lactose	163.4 ±24. 1/ 36.0 ± 8.6	43.0
9	3	5	143. 0± 9.3	Sucrose/Water	175.0 ±20. 5/ 46.0 ±10.5	53.0
10	10	9	90. 4± 9.0	Jaggery/Fructose	128.7 ±14. 6/102.22±33.3	25.0
11	5	10	161.4 ± 7.7	Jaggery/Lactose	176.0 ± 8. 6/ 45.2 ± 6.2	47.0
12	4	6	90. 4± 9.0	Jaggery/Water	127.0 ± 8. 4/ 33.3 ± 4.8	44.0
13	10	6	90. 4± 9.0	Fructose/Lactose	139.66±19. 0/ 55.0 ±10.0	22.0
14	7	6	129. 1±11.1	Fructose/Water	176.1 ±10.4 / 58.0 ± 5.3	23.0
15	2	5	168. 5+ 5.0	Lactose/Water	38.75+10.4 / 51.4 + 2.25	29.0
	2	5	167. 0+11.5	Lactose/Water	51.0 + 2.4 / 47.8 + 4.5	29.0

Figure 6. The sketch illustrates the entrance to the Maratha Fortress. The farm building is located on top right. The detailed plan of the building is given in the bottom figure.


N
Campus 1.5 km
Road
Bridge
Gate
Road
Rampart
Scale 11.92 m = 1cm

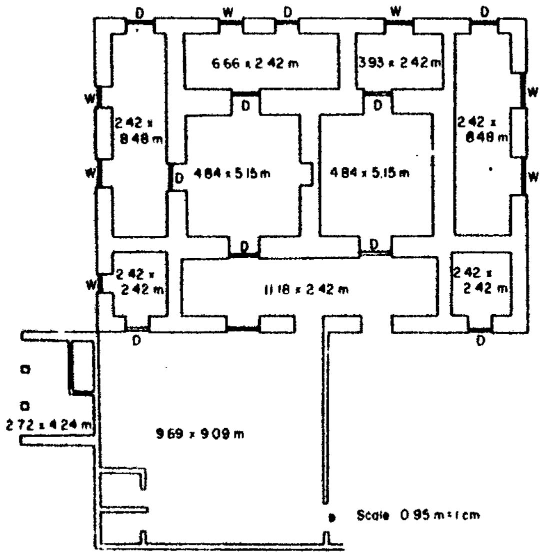

D
W
D
W
D
6.66 x 2.42 m
3.93 x 2.42 m
W
2.42 x 8.48 m
W
D
4.84 x 5.15 m
4.84 x 5.15 m
2.42 x 8.48 m
W
W
D
D
D
D
2.42 x 2.42 m
11.18 x 2.42 m
2.42 x 2.42 m
W
D
D
2.72 x 4.24 m
9.69 x 9.09 m
Scale 0.95 m = 1 cm

Fig. 6

Figure 7. *The arrangement of dishes at the field station, containing for example sucrose (S1, S2) and glucose (G1, G2). The position of the dishes was changed daily.*

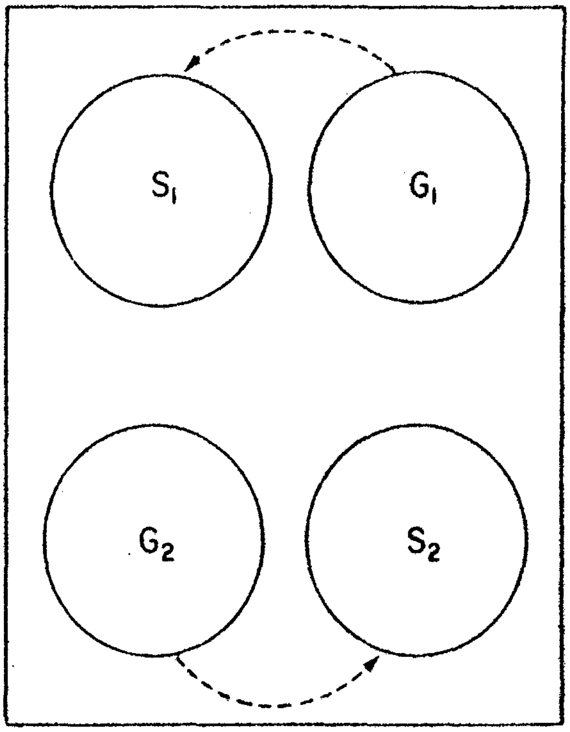


Fig. 7

Figure 8. Consumption of sucrose and fructose by the rats at fort. The latter was preferred only on the first day of the test. O, sucrose; ●, fructose.

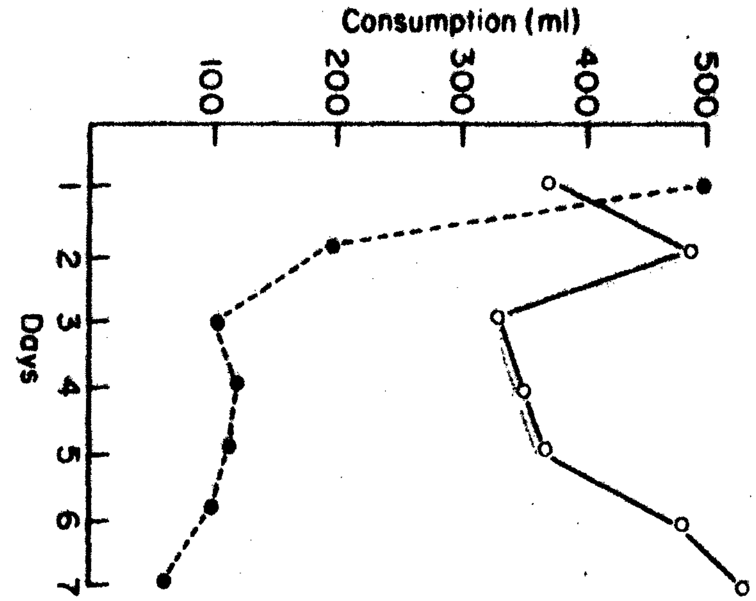


Fig. 8

Figure 9. *The relative consumption of jaggery and glucose in the field colony at fort. The choice alternated initially but then jaggery was clearly preferred. O, jaggery; ●, glucose.*

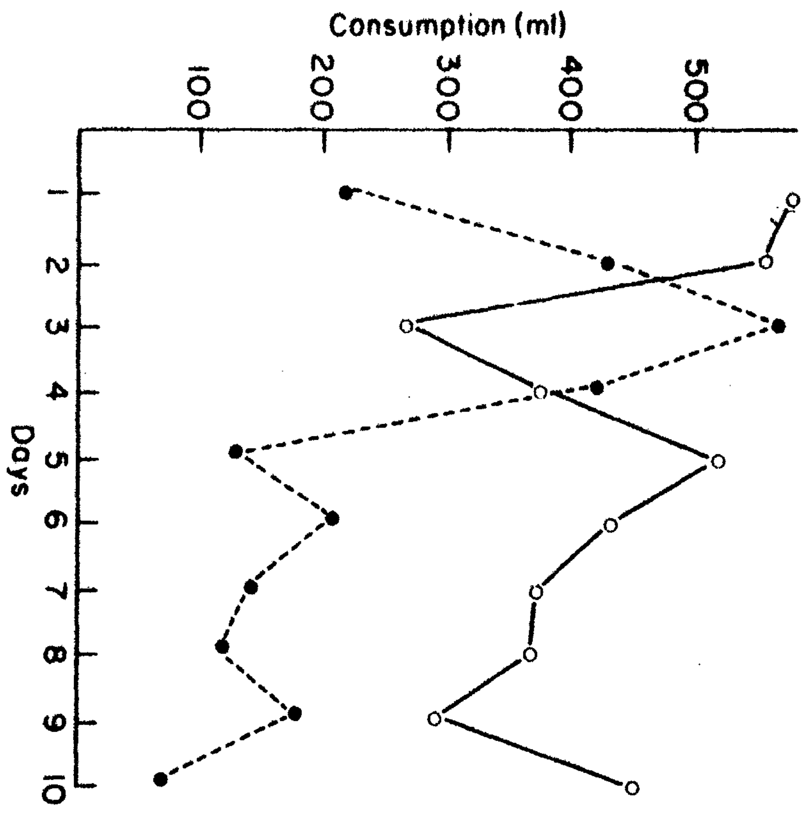


Fig. 9

Figure 10. The fort rats clearly preferred lactose to water on all days of the test. O, Lactose; ●, water.

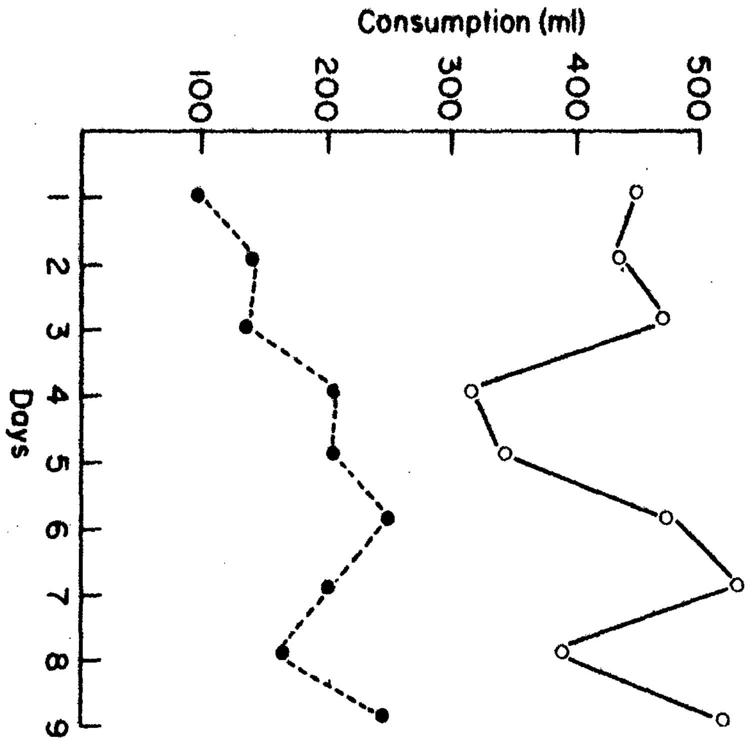
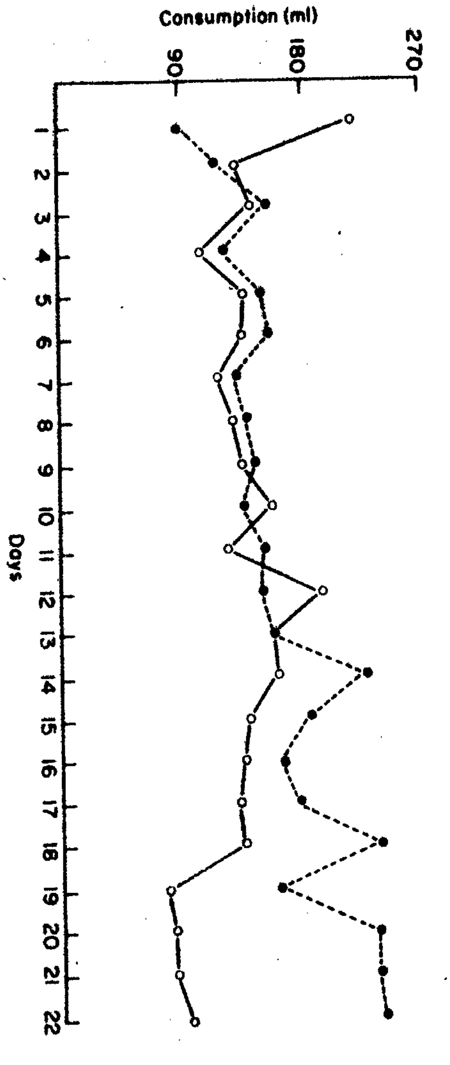


Fig. 10

Figure 11. *Relative intakes of glucose and sucrose in a laboratory colony of black rats. The choice was equivocal up to the 13th day, but eventually glucose was preferred. ●, Glucose; o, sucrose.*



Consumption (ml)
90
180
270
Days
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

Fig. 11

CHAPTER - IV

FOOD REQUIREMENT OF 'BLACK RAT', RATTUS RATTUS L.

Introduction

There have been several investigations on the food consumption of 'black rat' Rattus rattus L., (Harrison & Woodville 1950; Majumdar et al. 1969; Parrack 1969). But realising the regional variation in size and weight of this species (Harrison & Woodville 1949; Deoras & Gokhale 1958), it seemed desirable to estimate the food requirement of the rat, Rattus rattus rufescens, caught from various localities of Aligarh city. The results are reported here, together with an attempt to calculate the figure for translating food taken into number of rats for census work.

Material and Methods

Rats caught in 'wonder traps' were weighed and sexed by standard procedures (Evans et al. 1968). Pregnant females were excluded, and others were housed individually in wire-mesh cages of 1.17 X 0.88 X 0.35 m. The rats received a weighed surplus of unextracted wheatflour (wholemeal) in 15 cm diameter glass dishes. The residue was weighed on the succeeding day and the difference recorded. Replicates were run in all cases;

and the observations continued for a minimum period of ten days. There was an unlimited supply of drinking water. The data was statistically analysed by recommended methods (Bailey 1959; Chakravarti et al. 1967).

Results & Discussion

Table 7 makes clear the relationship between the amount of wholemeal eaten and body-weight of the rats. Juveniles weighing 45 gms or 50 days in age (Spillet 1969), consumed daily an amount of food equalling 21.35% of their body-weight. The figure decreased to 15.57% for sub-adults of 85 gm and 80 days in age; and varied from 8 to 11% for adults above 130 gm in weight. Evidently, consumption was high in fast-growing juveniles and sub-adults, and tended to level-off in older age groups (Harrison & Woodville 1950; Leslie & Ranson 1954; Majumdar et al. 1969).

The same exponential relation was demonstrated when logarithm of food consumption (y) was plotted against logarithm of body-weight (w). The calculated line of best fit log y = log a + b log w, was given by:

$$\log y = \log 0.3464 + 0.3853 \log w \text{ or } y = 0.3464\, w^{0.3853}$$

It was compared to similar data reported for brown rats Leslie & Ranson 1954). The hypothesis H: a=T. 5396, b=0.3853 was tested by the F-test for assigned linear *regression (Chakravarti et al. 1967). The test statistics was found to have the value 2.1856; which when compared with the tabulated value at (2.23) degrees of freedom, was significant at 5% level. This establishes the acceptance of the present results.*

The weight-structure of a representative population of black rats in Aligarh, may be taken from the records of 600 rats examined from July, 1971 to May, 1972. The data is summarized in Table 8, with observed weight distribution expressed per 1000 rats. The relationship demonstrated between food intake and body weight of rats (Table 7), gives a working basis for calculating the average consumption of wholemeal per member in this population.

According to Leslie & Ranson (1954), consumption per member per day can be calculated for a given population 'by applying the daily consumption of wheat calculated for the pivotal weights to the observed frequencies in each weight class and summing'. Presently this comes to 13.5 gm wholemeal consumed/member/day. The range of this average calculated from range of error of the regression line (0.3853 ± 0.08085) is negligible. The take of wholemeal in gm divided by the factor of 14 would give the approximate number of rats in a population of this weight-structure (Table 8).

Apparently the same factor can generally be used for census work; if the populations are not known to differ basically from that considered presently.

SUMMARY

'Roof' rats consumption of food in relation to its body weight, suggest that about 14 Gms. food/rat may be consumed in a normal population.

Thus *food consumption data can be translated into rat numbers by dividing it with the factor 14.*

Table 7 : Estimated intake of wholemeal per day by the rats.

TABLE - 7

Body Weight (gm)	Mean Daily Consumption (gm)	Mean daily Consumption % of Body Weight
35	8.7	24.86
45	9.6	21.35
55	10.4	18.9
65	11.3	17.38
75	12.5	16.55
85	13.2	15.52
95	13.8	14.52
105	14.1	13.4
115	14.4	12.09
125	14.7	11.7
135	14.8	10.9
145	15.0	10.34
155	15.4	9.93
165	15.5	9.39
175	15.8	9.02
185	16.2	8.75
195	16.3	8.35
210	18.6	8.85

Table 8 : Weight structure of a 'black rat' population.

TABLE - 8

Weight Group	Number of rats
up to—20	10
20-29	30
30-39	35
40-49	45
50-59	30
60-69	25
70-79	50
80-89	50
90-99	60
100-109	90
110-119	55
120-129	80
130-139	80
140-149	95
150-159	80
160-169	65
170-179	60
180-189	20
190-199	10
200-209	25
210-220	5

FOOD PREFERENCES OF FREE - LIVING "ROOF" RATS, RATTUS RATTUS L.

INTRODUCTION

Rattus rattus L., is widely distributed, on all lands and continents, except the colder regions; while it also occurs in most environments, from fields to storehouses and larders (Barnett & Prakash, 1975). Such outstanding success apparently rests on it's great adaptability (Barnett, 1975); as of feeding habits, which vary correspondingly over great geographical distances and in rural and urban areas (Harrison & Woodville, 1949; Khan, 1974; Barnett & Prakash, 1975). Differences are even observed between populations of the same locality; each of which probably possess a distinct "feeding pattern" (Jackson, 1965, 1972).

Therefore, feeding of each population also requires seperate study. Besides showing adaptability, it may even be essential in view of close relationship always recognised between, for example, studies of bait-preferences and methods commonly employed (poisoning) to control rodent pests (Chitty, 1954; Barnett, 1969). Accurate informations about preferences and aversions, can also be useful, it seems, for other aims of measuring consumption; as estimating abundance (relative census), or for studying the ecology and behaviour of the species with minimum of disturbance to the population (Doty, 1945; Chitty, 1954; Barbehenn, 1962).

However, food preferences of "free-living" "roof" rats have not been sufficiently explored. Todate, informations are limited to choice for foods (Candidate baits) often oberved before poisoing (Harrison & Woodville, 1949; Watson, 1954; Watson & Perry, 1954). Inferences have also been drawn from examination of stomach contents (Harrison, 1954); and similarly from damage caused to fruits, crops or stored foods (Jackson, 1965; Barnett & Prakash, 1975). Barring some obviously, food habits of captive rats, of diverse origins, observed in the laboratory; are of no great importance in this regards (Khan, 1974; Barnett, 1975).

Although not equally or simultaneously emphasised, there are many difficulties in studying the food habits of "free-living" rats (Chitty, 1954); specially in the investigation of bait-preferences (Elton & Ranson, 1954). These refer mainly to fluctuations of population, because of immigration; and bias which may be introduced in the results thus (Elton & Ranson, 1954). However, if observations are possible over long periods, with steady intakes at well-defined sites, many of the drawbacks are clearly overcome (Harrison, 1949). This has, however, not been frequently achieved.

Hence, an impression persists that suitable sites of infestation, where rats of one population sharing a common nest and the same sources of food and water may be permanent occupants, are very few. Contrary to this notion, there are many such sites in Aligarh (lat. $27^{o}34'$ $30''N$, long. $78^{o}4'$ $26''E$), in both urban and rural area; of which flour-mills and farm-buildings appear to be the most important. These are invariably infested with "roof" rats; competing species, *Mus musculus* L or *Bandicota bengalensis* Gray, are absent. Colonies confined to a flour-mill and farm-building, had also to be settled for eventually while making the present observations.

Observations were started at both sites on 30th December, 1974; and were continued, with unavoidable breaks in between, to end of 1977. Bait boxes were initially used; but afterwards the rats were baited at "surface" (Watson & Perry, 1954). Millet flour was given for about one month, before different kinds of foods were compared in combinations of two at a time. The responses of mill rats were found erratic; while work at this site had also to be suspended for certain periods because of objections from the owners. However, the fort rats were baited successfully, with several kinds of foods, over a long period (1975-1977). The results obtained at both sites are, however, discussed here.

STUDY AREAS

Location of study areas is shown in Fig.1 (Chapter I); details of farm-building have been given in Fig.6(Chapter III)

The flour-mill has urban, but the farm-building, though only 1.5 Km away from the campus, has more of a rural background.

Flour-mill:

The mill is surrounded by shoe-shops, laundaries and hair-dressers; of which it alone is suitable for infestation. It has two rooms; the milling machine is installed in the much larger front room.

The rats lived in the hollowed walls of the building, with only one opening to tunnels in machine room. It was located above the electric meter. The "hole" was reached by climbing on wooden cable-casings or the main door.

Cereals, and often pulses and spices, in bags and containers, were found strewn all over the rooms. The mill maintained regular working hours, from 08 to 16 hrs. The work was, however, occasionally extended to late hours.

Farm-building in Fort:

In the farm-building inside a ruined fortress, the rats occupied the big front room (4.84 X 5.15 m), packed *with barley and farm implements. The grains were later shifted to a smaller room in the rear. Within a few days, all the rats had also moved into it. They were baited successively, in both rooms. Both rooms were deeply tunneled, with holes close to ground.*

Predators either lived in or visited both sites regularly. Cats, dogs and mongooses (Herpestes sps) at the mill, and in addition snakes and monitor lizards (Varanus sps) at the other site; could be counted among them. Trapping or killing of rats by human agencies, was not knwon at either place.

MATERIAL AND METHODS

METHODS OF BAITING

Container Baiting: At start, two wooden boxes (0.9 X 0.3 X 0.3 m), with bases removed and a 10 cm passage cut on one face, were placed at each site; in machine room at mill and front room of farm building. The boxes were painted A & B; and were positioned close to each other and to the wall (Fig.12). The open side of each faced towards the wall.

Millet flour, in weighed amounts, was placed inside each box in dissection trays (31 X 26 X 8 cm). Consumption from the two trays, A & B, was recorded seperately.

Surface Baiting: After some weeks, the boxes were removed; but the trays were left at former positions, at a distance of 0.3 m. Consumption of millet flour was recorded as before. Other foods later replaced millet flour.

Test Foods: Choice of rats was observed for the following kinds of foods.

Cereals (Grains)

Millet (*Pennisetum typhoides* Burm), Wheat (*Triticum aestivum* Linn.), Maize (*Zea mays* Linn.), Sorghum (*Sorghum vulgare* Pers.), Barley (*Hordeum vulgare* Linn.), Paddy (*Oryza sativa* Linn.), Polished Rice

Cereals (Flours)

Unextracted : Wheat, Maize & Millet Flour
Extracted : Semolina, White flour

Pulses

Lentil (*Lens esculenta* Medic), Bengal Gram (*Cicer arienatum* Linn.), Blackgram (*Phaseolus mungo* Linn.), Green Gram (*P. aureus* Roxb.), Redgram (*Cajanus cajan* Linn.).

Whole grains, and husked and cracked grains of the same form were treated as two different kinds of foods (Khan, 1974).

Moist Foods

Moist Biscuits, Boiled rice, Soaked Wheat, Soaked Pulses

Sweet Foods

10% w/w mixture of cereal and cane-sugar, Cereal mixed with saccharine.

Oily Foods

5% w/w mixture of cereal with groundnut oil (Arachis hypogea Linn.).

Description of the foods, including mixtures, has been given by Khan (1974).

Measurement of Consumption

The study areas were visited daily between 9 to 11 a.m. Food in weighed amounts was given; the residue, including spillage, was weighed the next day (± 2g). Difference was taken to equal consumption; consumption from the two trays was totalled to obtain daily "take".

Intake of moist foods was calculated as according to Khan (1974).

Intake of foods due to calories was also calculated. Energy value of foods was read from Aykroyd's manual (1963); that of sugar and oily mixtures was found according to method described by Khan (1974).

Precautions Observed in Choice Tests:

When the choice tests started, position of the dishes was alternated daily. No order in testing of foods of any one kind was followed; care was also taken to avoid the presentation of same foods in successive tests. Fresh food was always offered.

Feeding positions were not unnecessarily disturbed; use of hands was kept to minimum, e.g. in touching trays or transfer of food.

Watching Rats

The mill rats came down after lights went out; latest by 8 p.m. However, the farm rats were active at all hours. An observer (E) was detailed to watch rats while feeding at both sites. However, regular observations could not be made.

Recording of 'Signs of Activity, Ectoparasites, Mortality:

Visible signs of rat activity-- excavations, damage to objects etc., were recorded daily. Presence of ectoparasites on or near the food trays was also noted. Dead rats, when found, were brought to laboratory; and sexed, weighed and autopsied.

Calculation of Rat Numbers

Rat numbers were found by dividing daily "take" by factor of 14.

Breeding in colonies was known from presence of pups; which were caught and weighed before being released at the same spots.

Weather Data:

Weather data was obtained from the local Metereological Office.

Statistical Analysis:

Methods described by Bailey (1959) and Lehner (1979) have been followed for statistical analysis of results.

RESULTS

The results are summarised in Tables 9 to 12; and illustrated from Fig.13 to 26. The results are described below under seperate sections.

Bait Consumption from Boxes

Baiting from boxes was continued for 38 days from start, at mill (30.12.1974 to 6.2.1975) and for 32 days at farm-building in the fort (30.12.1974 to 2.2.1975).

Lag in Entry: Neither of the two boxes placed at mill, was entered by rats on first two days. "Foot-marks" and faecal pellets were found inside, and on bait, on 3rd day; but actual consumption started only from 5th day (Fig.13).

At the farm-building, however, both boxes were entered on first day, and 121 g millet flour was eaten from the two trays (Fig.14).

Build-up of "Take":

Flour-mill: The same amount of bait, 60g, was eaten by mill rats from day 5 to 11. Maximum amount, 210g, was consumed on 22nd day, and minimum on day 31 (Fig.13).

The bait was often consumed from only one box, but the difference between mean intakes was very small (25.0 $\pm$ S.E. 3.300g millet flour from Box A; 26.31 $\pm$ S.E. 4.100g/day from Box B; d = 1.3, $P < 0.05$). Mean daily "take" equalled 54.14 $\pm$ S.E. 6.63g millet flour/day.

Farm-building: Unlike at the mill, bait-consumption at the farm-building increased from 121.00g at start to 170.00g on 8th day (Fig.14). Peak consumption, 200g, was observed on 15th day; and minimum intakes, 55.00g, on 29th & 30th days (Fig.14).

The bait was always eaten by rats from both boxes; but difference between mean intakes from two was much higher (58.61 $\pm$ S.E. 3.030g millet flour/day from Box A; 52.61 $\pm$ S.E. 3.600g/day from Box B) than that observed at mill (paired "t" test, $P < 0.05$).

Total daily "take" from boxes at this site, equalled 110.75 $\pm$ S.E. 5.00g/day.

Intake of Bait from Surface

Removal of Boxes: Fresh carcasses of male rats were recovered from inside boxes at both sites (Day 18 at mill; on days 22 & 27 at farm-building). Doubts arose, therefore, about free entry of rats into them; and so the boxes were removed.

Acceptance of Bait from Surface: After surface baiting was resorted to, no change in daily "take" was observed at either site . It was confirmed by consumption recorded during the subsequent choice tests.

Selection of Foods by Mill Rats

Choice tests at mill were started with dry pulses. These were completely rejected; the same foods were then offered in "moist" form. Other foods were, however, also accepted in same form.

Moist Foods: Among pulses presented in 'moist form', lentil was most preferred ($P < 0.05$); followed by cracked gram, husked green gram, whole lentil, whole green gram, whole blackgram, husked blackgram and redgram (paired "t" tests, $P < 0.05$; Fig.15).

Similarly, moist biscuit, moist wheat, boiled rice were selected in preference to their dry equivalents ($P < 0.05$; Fig.16).

Dry Foods: All kinds of foods in dry form - cereals, pulses, sweet foods, oily foods; were ignored by mill rats. Cereal flours were eaten in relatively greater amounts; but relative intakes fluctuated in a manner that no inference about choice could be deduced.

Selection of Foods by Fort Rats

The rats of farm-building at Fort accepted all kinds of foods, except pulses in dry form.

Whole Cereals: Of whole cereals, barley was preferred to all other kinds ($P < 0.05$; Table 9). Compared to it, only paddy, maize and millet were eaten in significant amounts; while wheat, sorghum and rice were almost ignored (Table 9; Fig.17). Obviously, the next choice was shown for paddy; but polished rice was consistently rejected (Table 9; Fig.17).

Millet, maize, wheat, sorghum and rice were selected in the order named (Table 9).

<u>Cereal Flours</u>: Semolina was most preferred among cereal flours ($P < 0.05$; Table 10). Compared to it, maize flour was more preferred for the first few days (Fig.18); but then the choice was reversed. Millet flour was preferred to wheat flour ($P < 0.05$; Table 10); while both were selected in preference to maize flour ($P < 0.05$; Table 10). White flour was, however, least preferred, (Table 10).

<u>Cereal and Cereal Flour</u>: In the choice between whole and ground cereal, the latter form was preferentially eaten. Thus, wheat flour was preferred to whole wheat; but the grains were also eaten in considerable amounts (Fig.19; Table 10).

<u>Cereal, Cereal Flour and Dry Pulses</u>: In the choice between cereal, cereal flour and pulses; the choice alternated between the former two before flour was selected ($P < 0.05$; Fig.19; Table 10). Of the three foods thus, millet flour was eventually preferred to whole millet ($P < 0.05$); while lentil was consistently rejected in comparison to both (Fig.19).

<u>Moist Pulses</u>: Pulses in moist forms were eaten in very large amounts. Equivocal choices were, however, not

shown.

As observed at mill, pulses were, however, selected in order lentil $>$ cracked gram $>$ husked green gram $>$ whole lentil $>$ husked blackgram $>$ whole blackgram $>$ red gram (Fig.20). The only difference noted was for the choice of blackgram; whole form was relatively more preferred at mill (Figs.15,20).

Other Moist Foods: Like moist pulses, other kinds of moist foods were also copiously consumed. The daily "take" showed a marked increase compared to that recorded preceeding to or afterwards, on dry foods, (Table 11).

Thus, moist biscuit, moist wheat and boiled rice were much preferred to dry alternatives provided ($P < 0.05$; Table 12; Fig.21).

Sweet Foods: Maize flour + sugar was eaten in greater amounts than plain maize flour on the first two days, and then declined on following days. The sweet and non-sweet food were eaten in almost equivalent amounts during the remainder of test, except the last day (Fig.22). Thus, the choice for sweet mixture was only slightly clear (Table 12; Fig.22).

Addition of saccharine clearly depressed the choice, it's mixture was rejected in comparison to plain maize flour ($P < 0.05$; Table 12).

Oily Food: Unlike it's sugar mixture, maize flour + oil was consistently preferred to plain maize flour, or non-oily alternative ($P < 0.05$; Fig.23; Table 12).

Sweet and Oily Food: In choice between maize flour + sugar and maize flour + oil, the rats selected the latter ($P < 0.05$; Fig.24; Table 12). The sugar mixture was, however, also preferred on two days (Fig.24).

Population Levels

Translated into numbers, bait consumption from boxes at maximum showed the presence of an almost equal number of rats, or 15, at both sites. But because of erratic feeding, no change in base-line estimates could be seen at the mill.

From the estimated 15 rats in January, however, an increase in population, to 23 rats, was obvious at farm-building from "takes" of boiled rice presented in month of February (Fig.25). There was, however, a very large increase in food consumption, irrespective of choice which included thus dry lentil, from 5.4.1975. Estimated population equalled 25 rats on 5th, 65 rats on 15th abd 45 rats on 30th of the same month (Fig.25).

There was an equally abrupt decline in "takes" in the following month, or May (Fig.25), corresponding to *which only 10 rats were left in month of June (Fig.25).*

An increase in population was indicated again in month of Sept. *(1975), when "takes" went up from 100 g, or 7 rats, at beginning to 450g, or 32 rats, on 20th of s same month (Fig.25). It declined again, but not to same levels as observed in summer (Fig.25).*

The same kind of fluctuations in populations were also noticed from April, 1976. The data have, however, been withheld for the sake of brevity.

Periods of Recovery of Rat Pups:

Rat pups, 18 to 20g in body-weight, were found near the food trays at farm-building, during the period March to May and July to September (1975); and similarly during the year 1976. Maximum number of pups, from 2 to 5, were recovered at a time in month of April. Otherwise, occurence was limited to only 1.

No pups, dead or alive, were ever found at the mill; not even by workers employed there.

Mortality

Besides the dead male rats recovered from bait-boxes at start, carcasses of two female rats (131g, 126g), were *found on two different occasions (22.4.1975 & 17.7.1975) near the food trays at farm-building. On either of two, each of which appeared fresh at time of recovery, there were no external marks of injury; but the eyes were missing. Absence of hairs around teats on closer examination, suggested that both were lactating or may be had just weaned the pups.*

Natural death of rats was not recorded at the other site, or flour-mill.

Ectoparasites

Large number of fleas (Xenopsella sps) were found on food trays or near about it at farm-building, during the rainy season (July to September). The flea numbers declined afterwards, and only few were seen by month of December (1975, 1976). None were found during the warmer periods (April to June).

Fleas were not seen in or near about the rat holes or milling machine at flour-mill.

No incidence of death in rats due to plague was noted at either site. The farm workers reported, however, seeing some bloated carcasses being eaten by cats and monitor lizards. It is known in India since early times *that cats do not eat rats which die of plague (Memoirs of Moghul Emperor Jehangir - Tuzuke Jahangiri; compiled around year 1620). Yet, whether lizards are able to prey upon the same and remain immune, is still to be known.*

Observations On Rats

Observations at farm-building showed that while feeding, females changed places on trays less frequently than males. The presence of some males was, however, noticed by all other rats; including the older females, which moved with their approach. Younger rats ran about much before settling down on the trays, usually after older rats had left. Social interactions continued, however, between feeding bouts; chasing was most frequently seen, while direct clashes were rare.

The rats at mill started descending as soon as the mill was closed, and entered the *milling machine, obviously to feed; while only a few remained outside to eat the cerealflour blown about on the floor. With frequent breaks in between, this continued for several hours; when the rats started moving around.*

The fort rats used either of the two or both hands, or mouth to pick-up food. After each small meal, they *walked about or ran, and else indulged in social interactions. Thus, food was eaten over a great many visits; which followed each other almost continously during bouts of variable duration Such continuity was broken by any loud sound or other kind of disturbance.*

DISCUSSION

Feeding of rodents is a far from unitary subject (Barnett, 1969). Of the kind of observations made, however, three broader aspects of it stand out for attention, viz., (1) Factors Affecting Acceptance of Bait, (2) Influence of Feeding Behaviour Components on Bait Consumption, (3) and Factors Affecting Selection of Foods.

There are, however, related matters too; treatment of which has been relegated to end of this discussion.

Factors Affecting Acceptance of Baits

Little is known about factors that influence the acceptance of baits by free-living "roof" rats. Thus, the subject has received infrequent attention, at diverse places *(Harrison, 1949; Watson & Perry, 1954; Barbehenn, 1962) ; inferences which may be generally applicable, are not derived from such data. As for it, "Norway" rats, R. norvegicus, have been thoroughly investigated; though* *in altogether different geographical settings (reviewed in Chitty, D.; 1954).*

Accordingly, not a few, but several factors are found to influence the acceptance of baits by "Norway" rats. These have been grouped roughly as, (1) External: natural food supply, cover, disturbances in environment, effeciency of baits, and baiting methods used, (2) and Internal : consisting of feeding habits, behaviour patterns as "new-object reaction", physiological factors as hunger(Chitty & Ranson, 1954; Rzoska, 1954). Effects of some have been elucidated since by numerous laboratory observations (reviewed by Barnett, 1975).

The two species, "roof" and "Norway" rats, are not similar in all respects; but still the relevance of factors that influence acceptance of baits by latter is recognised for acceptance of bait by former (Barbehenn, 1962). Effects of such factors on acceptance of baits by "roof" rats infesting mill and farm-building at fort, are also examined here.

Natural Food Supply:

"Norway" rats are found to accept baits readily when natural foods are either scarce or absent; and conversely, show less interest in baits when they are abundant (Chitty &

Ranson, 1954). Similarly, lack of variety in diet being eaten, tends to increase acceptance; while access to a large number of foods in the environment, has an adverse effect (Rzoska, 1954).

Although food was abundant in both experimental areas, it was available in greater variety to mill rats. This may have contributed to reluctance shown in eating baits at this site, for baits were always accepted at fort. Thus, variety, and not abundance, of foods affect, bait acceptance in colonies of wild "roof" rats.

Cover:

Wild rats like to eat foods under cover; but then the use of containers does not always facilitate feeding (Chitty & Ranson, 1954). Reasons cited regrading disadvantages of it's use, are that (1) the rats have to que-up to obtain food, (2) feeding in groups is inhibited, (3) and the entire population is seldom attracted because of difficulties experienced in getting food (Elton & Ranson, 1954; Rzoska, 1954).

Things similar to above seem to have affected the attempts made at beginning to bait "roof" rats from containers; which had to be removed eventually.

Disturbances in Environment:

Much difference was evident as for "disturbances in environment", between the two study areas. With absence of it, no kind of check apparently operated upon the fort rats; which were found active as a result, at all hours. In contrast, disturbances at mill, allowed the rats to come out only after dark, often at late hours. Probably this influenced acceptance; for baits were either eaten erratically or rejected at mill.

Thus, "roof" rats are not easily attracted to baits in environments constantly disturbed for one reason or the other, much like "Norway" rats (Chitty, 1954; Rzoska, 1954).

Efficiency of Baits:

Baiting was started with millet flour with a view to it's known superiority over both wheat flour and barley (Khan, 1974), the two pre-dominant natural foods reconnoitred respectively in mill and farm-building. Not immediately taken at mill, it was, however, easily accepted at fort. Success in baiting "roof" rats with dry foods, has, however, also been reported earlier (Harrison, 1949; Barbehenn, 1962).

However, the greater effeciency of moist foods as baits was demonstrated soon after at both sites. The mill *rats in fact, narrowed down their choice to only moist foods. The approaching summer had something to do with that phenomenon. Unlike them, fort rats accepted all kinds of foods; but the effeciency of moist foods was all the same shown by it's greater consumption; and the improvement which they affected in "take" of dry foods presented in succession.*

Thus, although moist foods are more effecient (Harrison & Woodville, 1949), it is also seen that choice of moist baits can make a marked difference to results only when used in summer, and not equally in winter season.

Effect of Baiting Methods Used:

The present use of boxes seems to corborate many of the informations given earlier about use of containers for baiting commensal rodent pests (Elton & Ranson, 1954). Thus, results of baiting with boxes at both sites, are found to have been influenced by two main factors, (1) the hesitation, or delay shown by rats in entering them, (2) and the numbers in which they were entered (Elton & Ranson, 1954; Rzoska, 1954; Barbehenn, 1962).

Evidently, "roof" rats show minimum delay or lag in entry (Doty, 1945; Elton & Ranson, 1954; Barbehenn, 1962); for even the greater lag observed at mill, of

4 days, is much less than that ordinarily displayed by "Narway" rats, from 7 to 15 days, (Chitty & Southern, 1954; Rzoska, 1954; Barnett, 1975). Obviously, the bait-boxes may often be entered on first day, as at fort.

Although, lag in entry may not have been of much consequence, there are grave suspicions about numbers in which boxes have been entered at either site. Presuambly, free access was denied to all rats; for that alone affected the build-up of take. It reached the plateau as late as on 15th day at fort, and on 22nd day at mill (Figs.13,14). Comparable time taken in case of "Norway" rats ismuch less, about 10 days (Chitty & Ranson, 1954; Rzoska, 1954).

That free-entry to boxes was restricted by social factors, is clearly suggested by recoveries made of fresh carcasses of male rats from them at both sites. Such disadvantages accruing from social interactions are apparently eliminated while baiting takes place from surface (Watson, 1954). Thus, observations at both sites showed that many rats are able to keep away from more dominant individuals. Otherwise also, there is greater chance of escape in an open situation; compared to that of being cornered inside boxes.

Thus, baits are easily accepted from surface than when offered from inside containers. Incidentally, surface *baiting has also been tried with success in similar environments previously, in places as far apart as Rangoon to Jaffa and Jerueslum (Harrison & Woodville, 1949; Watson & Perry, 1954).*

Internal Factors:

Although feeding habits are very important for acceptance of baits, these have been dealt with in the following section. Among other internal factors, both "new-object reaction" and physiological factors as thirst appear to have been very important.

New-object Reaction: Undoubtedly, the bait-boxes, or food trays if baiting had started without boxes, were like "new-objects" to rats in familiar areas (Cowan & Barnett, 1975). Their presence evoked, however, opposite reactions in the two colonies. e.g. of "avoidance" or withdrawl at mill and obversely of "approach and investigation" at farm-building. That obviously affected entry into bait-boxes, which lagged thus for some days at mill but not at farm-building.

Such conflicting reactions to new-objects from "roof" rats, have also been noticed earlier (Watson, 1954; Ewer, 1971); and that they may be shown in populations of the same area has also been indicated (Barnett & Prakash, 1975).

However, as the mill rats were used to "new-objects" in their midst, in form of bags and containers in which grains were brought for milling; avoidance of bait-boxes by them appeared somewhat anamolous. Thus, "Norway" rats that are strongly "neophobic" (Chitty & Shorten, 1946; Shorten, 1954; Barnett, 1975), show no avoidance of "new-objects" when similarly habituated to them while living on refuse tips and dumps. They are as a result, trapped easily (Boice & Boice, 1968).

Possibly, the avoidance response of mill rats did not exactly amount to a classical type of "new-object" reaction, as shown for example by many other rodent species (reviewed by Barnett, 1975). It could have been only "reluctance" on their part to investigate boxes or other objects when they had to concentrate on eating food (from a regular source) during the restricted period allowed each day. Thus, disturbances in environment, and habituation to a more rigid routine as a result; may have been responsible for the responses shown. More appropriately, the bait-boxes were ignored on the first few days at the mill.

Neverthless, the difference in responses affected the results of baiting; being successfull with normal "approach and investigation" response.

New-food Reaction: Foods encountered for the first time, are not immediately accepted by wild rats (Barnett, 1975). This behaviour has survival value, as of protecting them against poisoned baits. It is, however, rapidly overcome if the foods are beneficial or at least "safe" (Barnett et. al., 1978). It seems not to have affected the results, for example the fort rats showed no hesitation in eating millet flour on the very first day ; when they were quite unfamiliar to it.

Physiological Factors: Of physiological factors, hunger is found to induce rapid acceptance of baits (Rzoska, 1954). As indicated earlier, however, it is unlikely to be of any importance in places like Aligarh; where poor storage, insanitary conditions and very habits of the people of throwing out surpluses from each meal outside in street (Harrison & Woodville, 1949), gurantees abundance of food. It may often be difficult to obtain though, specially if overtly exposed in overcrowded localities; with dogs, cats and pigs roaming around.

Unlike it, thirst for water seems to exert a stronger influence on type of bait that may be taken rapidly. For the circumstances that enhance it's importance, it has also much wider relevance than presently realised. There is obviously a high demand of water in tropics (Barnett, 1969);

which is obviously aggravated by necessity of remaining holed-up for long hours, as at mill. The extra-water in moist baits, thus strongly attracts the rats.

Thus, "roof" rats are likely to eat moist baits without much hesitation, as has also been pointed out earlier (Harrison & Woodville, 1949; Watson, 1954; Barnett, 1969).

Effect of Feeding Behaviour Components on Consumption

Obviously, the actual consumption of baits is regulated by feeding behaviour components; of which some are of a general kind - method of eating, meal size etc. But others belong to a more specialised category and are of greater importance, like "omnivory" and "sampling behaviour" (reviewed by Barnett, 1969, 1975). The effects of and interrelationships between the various components, have, however, received adequate attention only in laboratory studies of feeding (Barnett & Spencer, 1951; Barnett, 1956; Barnett et. al., 1975, 1978). But that all components may contribute variously, to affect baiting results is, however, very certain.

Method of Eating: "Roof" rats seem to follow roughly the same methods of eating foods, as earlier described for

"Norway" rats (Barnett & Spencer, 1951; Barnett, 1956; Barnett, 1975). Grains are also thus de-husked before eating; though it does not appear to be a very specialised habit, as required for example by Heteromyids (Rosenzueig & Sterner, 1970).

Inconceivably the most convenient, eating methods adopted have also relevance to consumption of baits in two other ways, (1) about the kind of food used as bait, (2) and the type of container in which it is given. Thus, foods that can be easily swallowed may receive greater consideration; while an open type of container, like dissection trays, is likely to facilitate feeding. Narrow pipes, or bamboo pieces as used previously (Elton & Ranson, 1954; Barbehenn, 1962), may be disadvantageous in buildings. They were not used either.

Leaving baits on floor has also problems; it is scattered, and mixed with earth (Chitty & Ranson, 1954; Rzoska, 1954; Barnett & Prakash, 1975). This is also controlled by giving baits in open containers.

<u>Meal Size</u>: Feeding by free-living "roof" rats is also characterised by frequent visits to food trays, similar to that of "Norway" rats (Barnett & Spencer, 1951; Barnett, 1956). Food is presuambly eaten in very small

amounts at a time, or even merely sampled at; which has implications for more important behaviour components discussed in next sections.

Such feeding with restricted meal size can be disrupted, however, by slightest of disturbances in environment; and rats driven away once from bait points, may not chance to come back either. Probably this will result in erratic feeding; as also observed at mill, when only one of the two bait-boxes was often entered (Fig.13). Apparently, the effects of "disturbances in environment" are compounded, through interference in other processes.

Omnivory: The tendency to vary the diet, or "omnivory", is one of the most characteristic features of feeding behaviour of rodents (Barnett, 1969, 1975). It has great survival value, for performing functions as, (1) of reducing dependence on one or same sources food,
(2) allowing rapid changes in diet when required,
(3) and lastly of inducing exploration or search for alternative food sources even when adequate supplies are available (Barnett, 1975; Barnett et. al., 1978; Khan & Khan, 1979).

Apparently, omnivory is more pronounced in the natural state than what of it seems to have been consistently *indicated by results of laboratory tests on "roof" rats. It is exemplified by results of choice tests at fort and mill; specifically, by eating of inferior alternatives in considerable amounts, e.g. of dry foods in comparison to moist foods (Figs.16, 21), and of whole wheat in presence of wheat flour (Fig.19). On access to same choice, the former foods are eaten by captive rats in small amounts, or more often ignored by them (Khan, 1974). Otherwise too, the differences between consumption of any two foods offered at either site, are relatively much smaller (Tables 9-12); than differences generally seen in parallel tests conducted in laboratory (Khan, 1974).*

This greater expression of the behaviour in natural environment is expected, as for the reasons cited earlier. However, it confers both advantages, and disadvantages towards baiting of "roof" rats in wild state. That rats are likely to accept and consume baits offered to them because of omnivory, is thus beyond question. However, it is also clear on the other hand that they will not stop eating natural foods, nor for that matter are ever likely to depend wholly on baits offered to them from outside.

Sampling Behaviour: Eating of all foods, and eating of each always by small amounts; is another aspect of feeding *behaviour of wild rodents of great importance. Linked to omnivory, this has also survival value (Kamal & Khan, 1977; Kumari & Khan, 1978; Khan & Khan, 1979; Siddiqui & Khan, 1979).*

"Sampling" mainly helps in testing foods for their affects (Rozin & Kalat, 1971); so that rats are able to discriminate between toxic and "safe" foods. On this basis, new sources of food are located, feeding is initiated and favourable feeding habits are eventually developed (Barnett, 1975; Barnett et. al., 1975, 1978).

In the immediate context, it seems to show that baits selected from amongst the foods eaten in the environment, may be readily eaten in comparison to those not encountered in it. Accordingly, the results of choice tests must have been affected; but that it might have altered the outcome, is doubtfull.

Factors Influencing Selection of Foods:

In favourable, or undisturbed, environment, e.g. fort, clear choices are shown between two or more baits offered at a time by eating them obviously in unequal amounts (Tables 9-12). Thus, results very similar to that in laboratory, are also obtained by comparing foods on free-living "roof" rats.

When tested in laboratory, however, wild rats are found to select foods in linear orders (Spillet, 1968; Khan, 1974; Kumari & Khan, 1978); which speaks of their stable preferences and aversions (Barnett, 1969, 1975). This is, however, not a universal phenomenon; for many others, *R. meltada* Ryley, *Bandocita bengalensis* Gray, in similar situations are found to show contradictory choices for foods (Spillet, 1968; Jain *et. al.*, 1974; Kamal & Khan, 1977; Siddiqui & Khan, 1979). There is some evidence that slection of foods in preferential orders is a product of commensalism, rather than of feeding adaptations in more natural environments (Khan & Khan, 1979).

Thus, the free-living "roof" rats studied, are found to have shown, as expected, orderly choices between foods of each kind offered. Whole cereals were selected at fort in order - barley > paddy > millet > maize > wheat > sorghum > rice; cereal flours in order, semolina > millet flour > wheat flour > maize flour > white flour. Pulses in moist form were selected at both sites in order, cracked lentil > cracked Bengal gram > husked green gram > whole green gram > whole lentil > husked black-gram > whole blackgram > red gram (Fig.20).

Except for pulses, however, fort rats did not select other kinds of foods in the same heirarchies or orders as chosen for example by them under simulated conditions in *the laboratory. Thus, barley has been analysed as the most distasteful food in laboratory tests, while maize flour is preferred more than wheat flour (Khan, 1974). Thus, although selected in linear orders, the exact choice for foods of free-living "roof" rats may vary, at least from what is found in laboratory tests.*

That such differences in feeding habits may arise out of variable effects of different factors that determine choice, is, however, evident from the following.

Social Factors: The "marked" preference shown by fort rats to barley from amongst whole cereals (Table 9; Fig.17), was obviously related to it's exclusive presence as natural food in their environment, Evidently, the choice for it developed at an early age, lasted consistently through the adult life. That social factors actually determine feeding patterns, as demonstrated by studies of development of feeding habits of rats in the laboratory (Galef & Clark, 1972), is also confirmed by present observations in the field.

It also clarifies, or confirms, the various postulations regarding feeding of rodents made on the basis of observations in the laboratory, viz. (1) that choice of foods needs to be known by vigorous researches in the field, (2) foods normally eaten in environment are likely to make better baits, (3) and that each population requires *seperate study of it's feeding habits (Barnett & Prakash, 1975). Similarly, the existence of "feeding traditions", and based on it the reality of "proto-culture" in rodent societies, is also confirmed (Schein,& Orgein, 1953; Jackson, 1965; Garcia et. al., 1974).*

Texture:

Omnivorous rats normally prefer finely-divided foods to whole grains; and foods of "smooth" and "soft" texture to "coarse" or "hard" foods (Barnett, 1969; Barnett & Prakash, 1975). Fort rats also selected ground form of wheat in comparison to whole grain, and preferred similarly semolina for it's large and smooth granules among cereal flours (Table 10; Figs.18, 19). However, no effect of texture was seen on choice between whole cereals (Table 9), and for obvious reasons.

Greater choice seen for barley and paddy, which closely resembled it (Table 9), differs, however, remarkably from all previous descriptions of preferences of "roof" rats observed between foods of different textural state, either in laboratory or in field (Watson & Perry, 1954; Khan, 1974). But that omnivorous rats may often develop such unique "likeness" for foods of inferior texture, is, however, clearly demostrated (Fig.17).

Inspite of great likeness for coarse foods, fort rats are found to have rejected, however, hard foods, as pulses. Probably this may have been responsible for down-grading of wheat and maize in order of choice shown for whole cereals (Table 9). Moist foods must have been liked obviously, for it's softness too (Khan, 1974).

Taste

The effect of taste, like texture, is not evident from choices shown by fort rats between whole cereals; for barley is obviously not the most palatable of them all (Khan, 1974). However, selections of pulses suggests, as demonstrated likewise in laboratory experiments, that they are perhaps preferred in order of palatability of their tastes (Khan, 1974).

Surprisingly, however, no indication about the role of taste in forming choice of free-living "roof" rats, is obtained from comparison of sugar mixture to it's non-sweet alternative (Fig.22). The fact that the consumption of plain cereal exceeded that of sugar mixture on some days of the test (Fig.22), even shows that strong preference for sweet taste was somewhat lacking in fort rats. This contradicts all previous observations of it's effect (Barnett & Spencer, 1953; Barnett, 1969; Khan, 1974); for foods sweetened with sugar are very much liked. Preference *for sweet foods has also great adaptive value (Garcia et. al., 1974).*

Probably, the "new-food reaction" towards sugar mixtures persisted far longer than would be expected. But then sugar solutions are readily accepted and consumed in large amounts by the same rats! There is no plausible reason to account for the marginal preference shown by fort rats to sugar mixture in comparison to plain alternative (Fig.22); though the rejection of food sweetened with saccharine is in line with responses shown in laboratory tests too (Khan, 1974).

Thus, sweetness does not generally increase preference, as widely believed; familiarity with sweet foods is perhaps a pre-requisite.

Energy Value:

Omnivorous rats select foods of superior energy value; and decline the alternatives of low calorific value (Barnett, 1969; 1975). This is reflected by selection of cereals and pulses by wild rodents in an order. which closely corresponds to differences in energy value of the same foods (Khan, 1974; Kumari & Khan, 1978; Khan & Khan, 1979). That also reveals a tendency, widely prevalent among mammals, of obtaining maximum energy in minimum time, and with perhaps least expenditure of it (Smith & Follmer, 1972).

Selection of high energy foods has also other advantages; surplus energy so obtained may also lead to gain in body-weight (Khan, 1974); the benefits of which in the natural environment, need hardly to be emphasised (Barnett, 1975; Barnett & Prakash, 1975).

Evidently, foods of high energy value are also favoured by free-living "roof" rats. Thus, mixture of cereal with oil was markedly preferred by fort rats (Fig.23; Table 12); it was also consumed in comparison to sugar mixture (Fig. 24; Table 12), by a margin wider than that usually observed in laboratory tests (Khan, 1974). It seems that the ease with which the oily foods can be swallowed, is also an important consideration in natural environment; besides the benefits which eating of it confer (Khan, 1974; Kumari & Khan, 1978; Khan & Khan, 1979). The latter kind of effects are thus always slow to appear (Barnett, 1975; Barnett & Prakash, 1975).

However, preferential orders for cereals demonstrated of fort rats, do not fully confirm to linear differences in energy value of individual foods. Obviously, foods only slightly superior in energy value, as millet, do not become more acceptable than those, like barley, for eating of which a tradition has continued in the population.

Regulation of Daily Food Intake:

Irrespective of choices given at fort, peaks and troughs in total "take" during particular periods, seem to have alternated regularly; suggesting that in natural environment also excesses of one day are balanced - off by reducing intake on following days. Of this, nothing is known, however, about contribution of baits to total food intake of each rat at the site.

Population Estimates and Trends:

As referred to already, food consumption is readily translated into rat numbers (Chitty & Southern, 1954); but the method has been used only to find relative abundance of rats in selected areas (Barbehenn, 1962). The present observations also show that reliance on it to obtain accurate rat numbers may be misplaced for several reasons; specially because of the partial contribution of baits to diet of rats, and depending upon the kind of bait chosen such "takes" can also be over - or under-estimates of actual consumption. Thus, the possibilities of over-estimating or under-estimating the population can always be greater than of getting accurate estimates.

However, like relative abundance, population trends are also adequately reflected by changes in food consumption of a population over a long-period. Thus, the large increase in "takes", noticed in month of April at fort probably corresponded to breeding in the population. Similar changes occured again during the period July to September; and each time breeding was confirmed by recovery of rat pups at the site.

That seems to show that breeding coincided with increase in air-temperatures, or with advent of warmer periods; but stopped again when temperatures became very high, i.e. during the actual summer season. Breeding started again in the rainy season, and continued, but with lower rates of reproduction, till next winter. There are thus two unequal peaks of breeding, with larger one, as food consumption data show, after the winter and smaller peak in the period before it. This kind of changes in reproductive cycle of "roof" rats, have also been demonstrated by direct observation of reproduction in places more or less similar in climatic conditions to Aligarh (Southwick, 1969).

Decline of estimated population during the summer months, clarifies that reproduction is controlled by prevailing temperatures rather than by availability of food, as also often found (Taylor & Green, 1976). The causes of decline are, however, not clear. It may have been reduced because of large scale dispersion, or heavy mortality; but there is not much evidence to support either.

Apparently, the population at fort must have sccumbed to predatory pressure; as the presence of a large number of predators seemed to show.

GENERAL REMARKS

Acceptance of baits by "free-living" "roof" rats, is decided by an interaction of various external and internal factors that influence it. Seemingly, the inner dynamics of it can vary from environment; depending on which of them become "limiting" in effect "Disturbances in environment" has that importance in case of rats living in close association with man; followed by type of baits selected and methods used.

Baiting is a process essentially, which induces rats to eat foods other than those found in the natural environment. This is possible because of their "omnivory"; but then actual consumption takes place with great caution. Although initiated rapidly, feeding is thus disrupted easily. Then, habituation to regular food sources, increases the chances of failure of baiting. Feeding behaviour components have also relevance for consumption of baits in natural environment.

More rats are attracted by presentation of moist baits; and by baiting with two rather than with one food.

The opportunity of satiating two needs, of food and water, at a time; and of obtaining a more favourable diet, lie behind this. However, the two foods are usually eaten in unequal amounts; so that choices are clearly shown. Choices developed on account of social factors, are only stable; and form the basis of distinctness in "feeding patterns" possessed.

Superiority in taste or texture does not influence the choice of rats; but that of energy value of baits does. However, high energy value foods that are also easy to swallow, are actually favoured. Tasteless oil is, therefore, a better additive than sugar, which alters the taste, for baiting free-living "roof" rats. Irrespective of choice, however, the rats desist from depending wholly on baits for daily needs of food.

Thus, although easily translated into rat number, food consumption data are not an accurate estimate of the population. Trends in population are, however, satisfactorily revealed by such data; duration of breeding is also known along with oscillations of the population. Occurence of breeding is corborated by recovery of rat pups; which seem to leave the nest early.

Ectoparasites, Xenopsylla etc, appear with increase of humidity in the environment; or abound in rainy season, *disappearing by the time of winter. No mortality is caused in host population as a result; their population is kept in check by predators.*

These facts cell attention to the following:

1. Different kinds of environments have to be surveyed for assessing the relative importance of various factors that determine acceptance of baits.

2. Effects of and interrelationships between different feeding behaviour components have to studied in the natural environment, in order to clarify their role in regulating consumption of baits.

3. By seperate experimental designs, common foods and attractive baits prepared need to be compared to main foods eaten by rats in their environment. The baits can be ranked on that basis, taking the choice for pre-dominant food as unity.

4. Accuracy of food consumption data as a measure of "roof" rat population, has to be analysed further, in variable situations. The limits of accuracy on either side, have to be defined before it becomes a standard procedure for population study.

SUMMARY:

Rats, Rattus rattus L., belonging to two distinct

populations, infesting respectively a flour-mill and an isolated farm-building inside a fort, were baited in their home-area. Both the methods, of baiting with containers and from surface, in that sequence, were tried. The former became unsuccessfull because of social tensions, the fatal results of which were recorded at both sites. Baiting from surface succeeded with only moist foods at mill; but gave satisfactory results with all kinds of baits at fort. Details of results of baiting obtained at the two sites, have been discussed.

Observations of rats while feeding, showed that the same methods of eating were employed by the free-living rats as that described earlier for similar other species from laboratory observations. Similarly, consumption occured by small meal-size, and was interspersed over a large period of time; and large number of visits were made to food point. Relevance of feeding behaviour components to acceptance and consumption of bait in the natural environment, have been analysed.

By choice tests, preference of mill rats was evaluated for only moist foods; but preferences of fort rats were found for a wide vaiety of foods. Foods were selected in linear orders; the exact choices for some foods differed from that of preferential orders analysed by laboratory tests. Evidently, greater choice for inferior foods were demonstrated. Apparently, effect of social factors on food preferences was greater than that of other factors as taste, texture a energy value. As choices developed on account of social factors dominated the feeding habits fully, marked distinctness of "feeding patterns" was also demonstrated.

Food consumption data were also utilized in estimating relative abundance. Trends in population thus measured of fort rats, revealed large-scale breeding during the month of April. Population declined to minimum in following summer months - of June; but increased again with breeding during the rainy-season. Reproductive rates were presuambly lower in this period than in April. Occurence of breeding was corborated by recovery of rat pups in home area; which seemed to leave the nest at an early age.

Ectoparasites, a fleas, were recorded at fort in very large numbers during rainy season. Natural mortality was only incidental, there was no evidence of large-scale dispersal of rats either. Apparantly, the population was kept in check mainly by predetors.

Table 9 : Consumption of whole cereals, in gms/day ± S.E.(standard errors of the mean), by rats of the farm building at fort.

TABLE - 9

Test No.	Days from start	Choice offered	Mean Daily Intake, g/day ± S.E.	% Calories	Total consumption g/day ± S.E.
16	230-236	Barley	165 .75 ± 9.51	65	
	(18-24/8/75)	Millet	85.51 ± 10.55	35	251.33 ± 8.72
17	257-263	Barley	270.00 ± 16.00	62	
	(13-19/9/75)	Maize	168.57 ± 24.44	38	438.81 ± 19.00
18	225-229	Barley	260.00 ± 28.00	88	
	(13-17/8/75)	Wheat	34.00 ± 5.00	12	294.00 ± 28.00
19	208-213	Barley	255.00 ± 12.81	95	
	(26-31/7/75)	Sorghum	15.00 ± 4.72	5	270.00 ± 14.18
20	214-219	Barley	178.30 ± 37.22	87	
	(1 -6 /8/75)	Rice	28.31 ± 7.41	13	266.00 ± 10.41
21	294-300	Barley	177.11 ± 14.62	67	
	(20-26/10/75)	Paddy	100.00 ± 34.00	37	277.11 ± 13.51
22	343-349	Paddy	181.20 ± 11.22	73	
	(8-14/12/75)	Millet	61.00 ± 8.11	27	241.77 ± 13.10

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Table 9 (Contd.)

Test No.	Days from start	Choice offered	Mean Daily Intake, g/day ± S.E.	% Calories	Total consumption g/day ± S.E.
23	336-342 (1-7/12/75)	Paddy	180.30 ± 7.21	74	
		Maize	61.40 ± 11.10	26	242.33 ± 9.81
24	308-314 (3-9/11/75)	Paddy	192.33 ± 7.50	81	
		Wheat	41.31 ± 7.10	19	233.71 ± 8.32
25	322-328 (17-23/11/75)	Paddy	182.97 ± 8.17	92	
		Sorghum	69.72 ± 8.00	8	251.81 ± 8.00
26	329-335 (24-30/11/75)	Paddy	203.11 ± 14.16	83	
		Rice	41.00 ± 9.25	17	244.71 ± 11.36
27	200-207 (18-25/7/75)	Millet	207.51 ± 8.31	65	
		Maize	120.55 ± 19.51	35	328.75 ± 27.71
28	220-224 (17-12/8/75)	Millet	135.00 ± 17.55	61	
		Wheat	85.00 ± 17.00	39	245.00 ± 43.00
29	238-242 (25-28/8/75)	Millet	118.00 ± 20.00	67	
		Sorghum	60.00 ± 12.44	33	178.00 ± 11.71
30	271-278 (27.9-4.10/75)	Millet	163.11 ± 9.72	70	
		Rice	76.00 ± 10.11	30	239.11 ± 6.00

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Table 9 Contd.

Test No.	Days from start	Choice Offered	Mean Daily Intake, g/day ± S.E.	% Calories	Total consumption g/day ± S.E.
31	249-257	Maize	145.70 ± 32.00	54	
	(4-12/9/75)	Wheat	112.20 ± 11.30	46	258.00 ± 22.3
32	264-270	Maize	167.11 ± 24.22	61	
	(20-26/9/75)	Sorghum	104.31 ± 16.42	39	271.44 ± 32.44
33	279-285	Maize	101.14 ± 19.22	89	
	(5-11/10/75)	Rice	12.41 ± 1.29	11	115.71 ± 23.66
34	189-199	Wheat	119.54 ± 17.51	54	
	(7-17/7/75)	Sorghum	108.63 ± 16.31	46	229.11 ± 43.21
35	243-248	Wheat	156.00 ± 6.04	70	
	(29.8-3.9/75)	Rice	70.00 ± 2.39	30	225.61 ± 9.00
36	315-321	Sorghum	172.33 ± 11.61	77	
	(10-16/11/75)	Rice	53.55 ± 7.12	23	226.55 ± 9.41

Table 10 : Relative consumption of cereal flours by fort rats. Results of comparison between whole wheat and wheat flour, cereal and pulse, cereal and pulse and flour are also given.

TABLE 10

Test No.	Days from start	Choice offered	Mean Daily Intake, g/day ± S.E.	% Calories	Total consumption g/day ± S.E.
1	145 - 153	Semolina	75.55 ± 4.41	58	
	(27.5-4.6/75)	Maize flour	62.23 ± 5.21	42	137.79 ± 2.63
2	136 - 144	Semolina	80.00 ± 10.91	74	
	(19-26/5/75)	Wheat flour	38.70 ± 5.00	26	118.72 ± 26.83
3	350 - 356	Semolina	185.00 ± 3.11	62	
	(15-21/12/75)	Millet flour	106.12 ± 2.11	38	291.00 ± 3.00
4	50 - 56	Millet flour	95.00 ± 7.00	68	
	(18-22/2/75)	Maize flour	22.66 ± 9.00	32	135.00 ± 14.88
5	36 - 42	Millet flour	97.11 ± 12.11	95	
	(3-8/2/75)	Wheat flour	1.43 ± 0.22	5	98.55 ± 11.81
6	67 - 76	Maize flour	64.00 ± 4.00	49	
	(24.2-4.3/75)	Wheat flour	67.00 ± 6.77	51	131.00 ± 5.66
7	110 - 117	Wheat flour	330.00 ± 29.21	55	
	(21-27/6/75)	Whole wheat	262.85 ± 7.31	45	592.85 ± 67.00
8	119 - 126	Millet	262.55 ± 28.9	68	
	(28.4-5.5/75)	Lentil	93.71 ± 16.82	32	356.22 ± 45.81
9	94 - 106	Millet flour	288.44 ± 41.33	46	
	(5-17/4/75)	Whole Millet	214.66 ± 21.81	36	
		Lentil	107.61 ± 18.00	18	610.73 ± 47.22

White flour was eaten in very small amounts ($<$1.09).

Table 11 : Amount of moist foods eaten by fort rats, when given with an alternative dry food .

TABLE - 11

Test No.	Days from start	Choice offered	Mean Daily Intake, g/day ± S.E.	% Calories	Total consumption g/day ± S.E.
10	41 - 48	Boiled Rice	270.66 ± 20.71	88	
	(9-17/2/75)	Wheat Flour	36.25 ± 5.41	12	306.81 ± 18.81
11	127 - 132	Soaked Wheat	340.81 ± 18.82	57	
	(6-10/5/75)	Millet Flour	120.81 ± 22.17	43	461.61 ± 18.88
12	134 - 140	Moist Biscuit	607.11 ± 88.00	73	
	(12-17/5/75)	Wheat Flour	80.00 ± 17.72	27	661.44 ± 71.99

Table 12 : Results of choice tests with mixtures of sugar and oil offered with plain equivalents. Relative intakes of sweets and oily foods is also given.

TABLE - 12

Test No.	Days from start	Choice offered	Mean Daily Intake, g/day ± S.E.	% Calories	Total consumption g/day ± S.E.
13	66 - 77	Maize Fl.+Sugar	49.11 ± 6.61	58	
	(6-17/3/75)	Maize Flour	43.25 ± 1.62	42	92.44 ± 7.00
14	78 - 87	Maize Fl.+Oil	117.00 ± 6.31	72	
	(18-25/3/75)	Maize Flour	41.00 ± 6.83	28	158.00 ± 4.91
15	89 - 95	Maize Fl.+Oil	98.55 ± 14.71	66	
	(29.3-4/4/75)	Maize Fl.+Sugar	54.20 ± 18.71	34	152.88 ± 20.50

Saccharin mixture was not eaten

Figure 12 : The arrangement of bait boxes at the experimental site (not to scale).

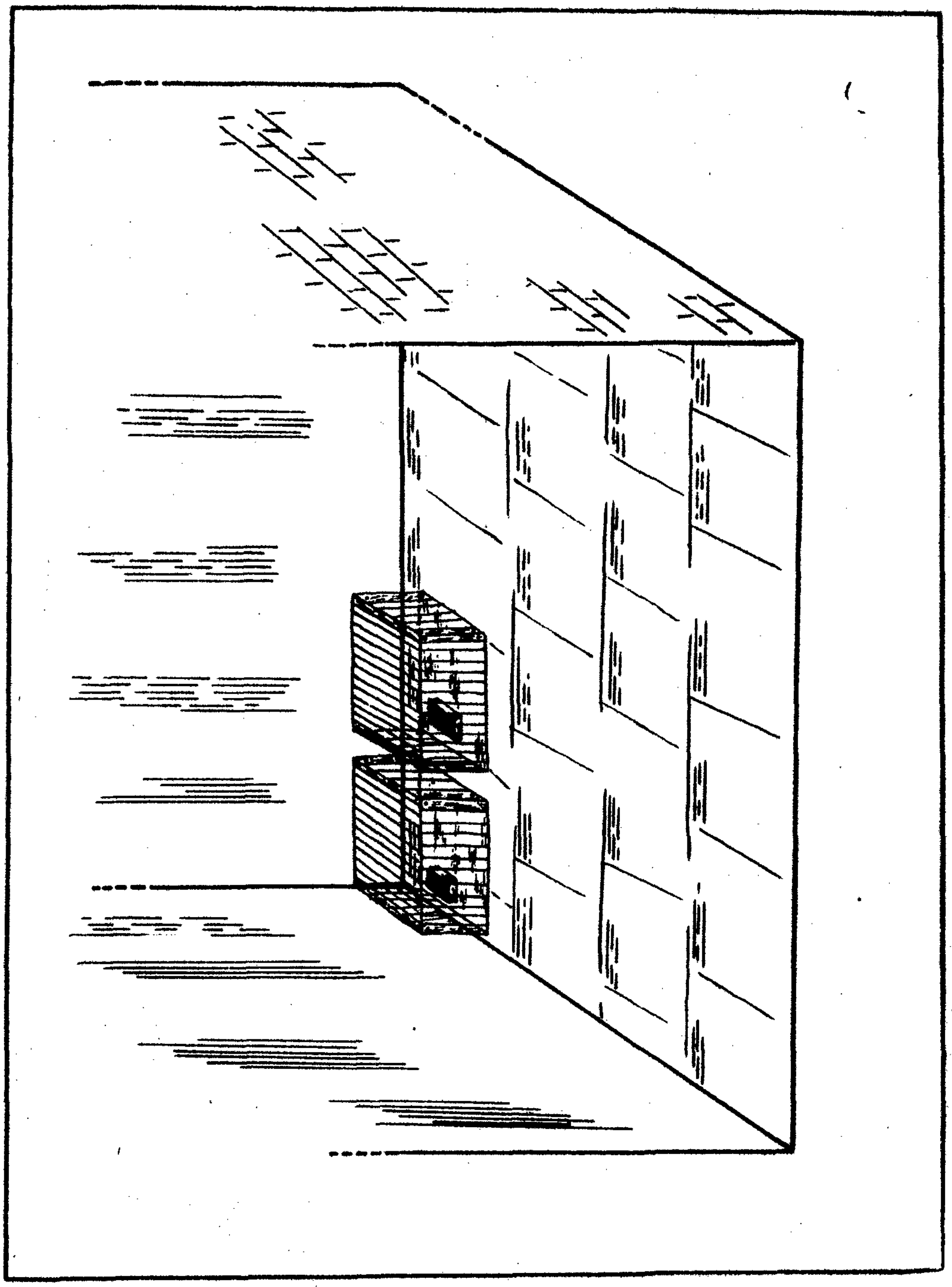
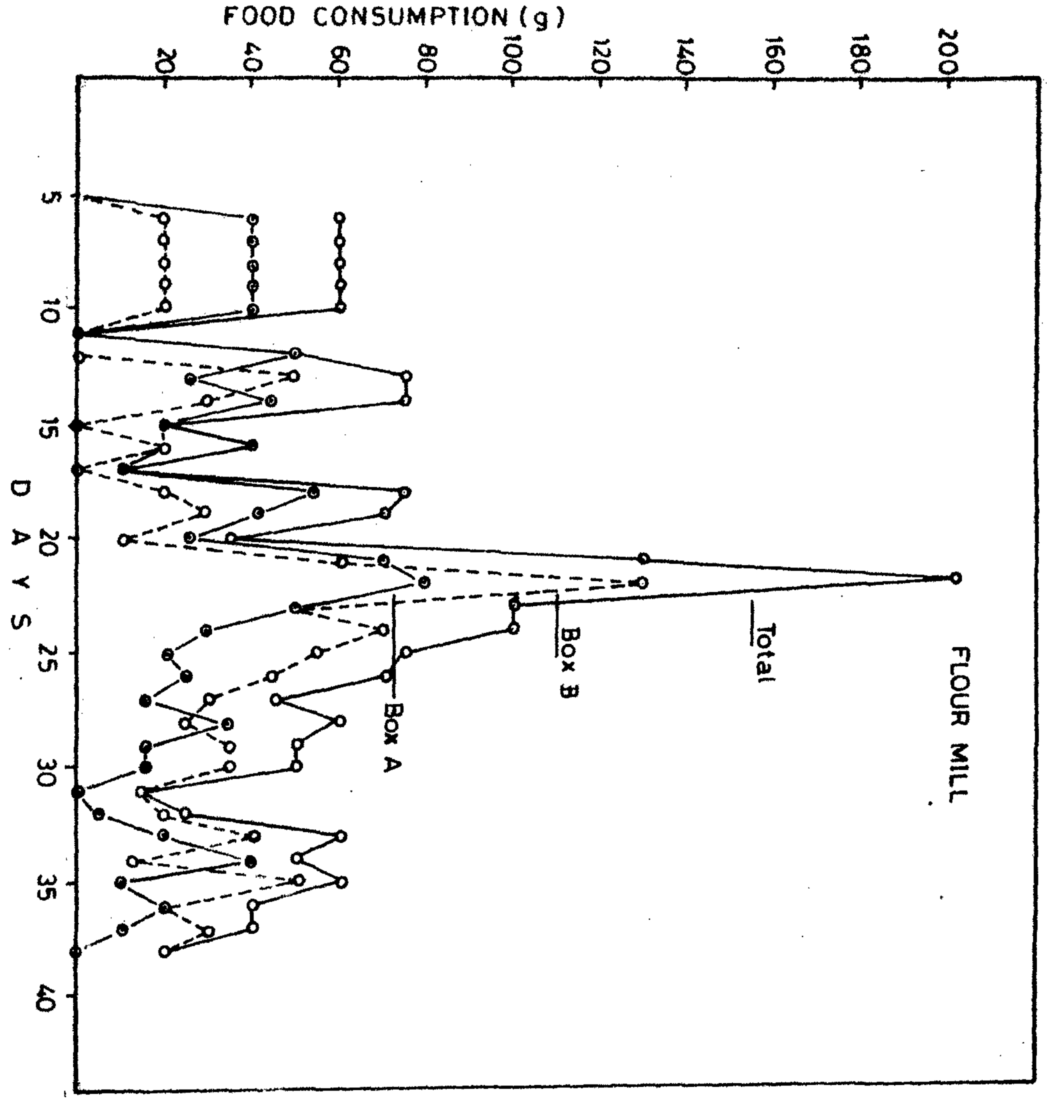


Fig. 12

Figure 13 : Takes of bait from the boxes at mill. The bait was often eaten only from one of the two boxes.



FOOD CONSUMPTION (g)
20
40
60
80
100
120
140
160
180
200
5
10
15
20
25
30
35
40
D A Y S
FLOUR MILL
Total
Box B
Box A

Fig. 13

Figure 14 : The amount of bait eaten from the boxes at fort. Total in take is also plotted.

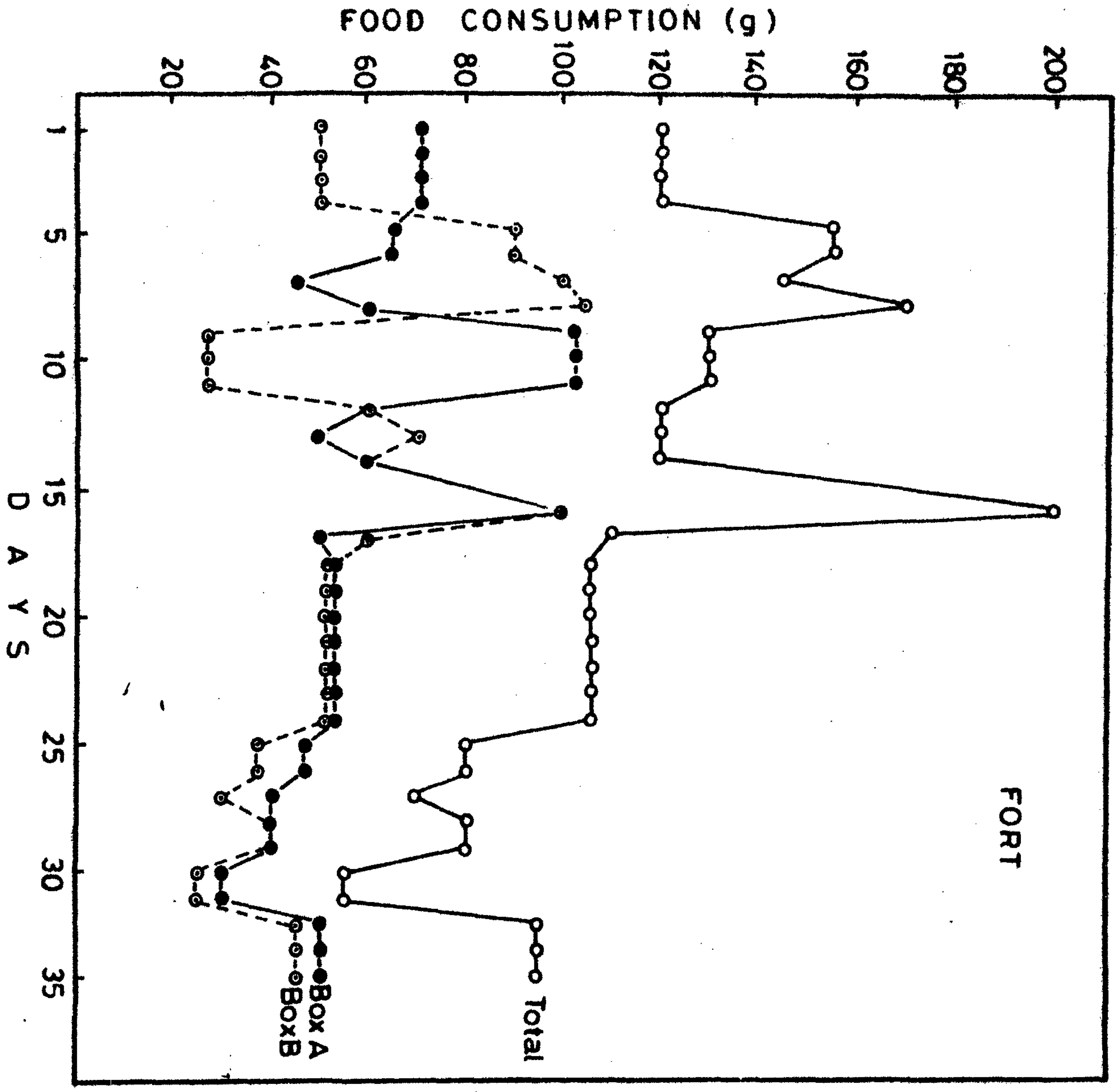

FOOD CONSUMPTION (g)
20
40
60
80
100
120
140
160
180
200
FORT
1
5
10
15
20
25
30
35
D A Y S
Total
Box A
Box B

Fig. 14

Figure 15. Mean consumption of pulses offered two at a time by mill rats. Husked lentil was most preferred, red gram was liked the least.

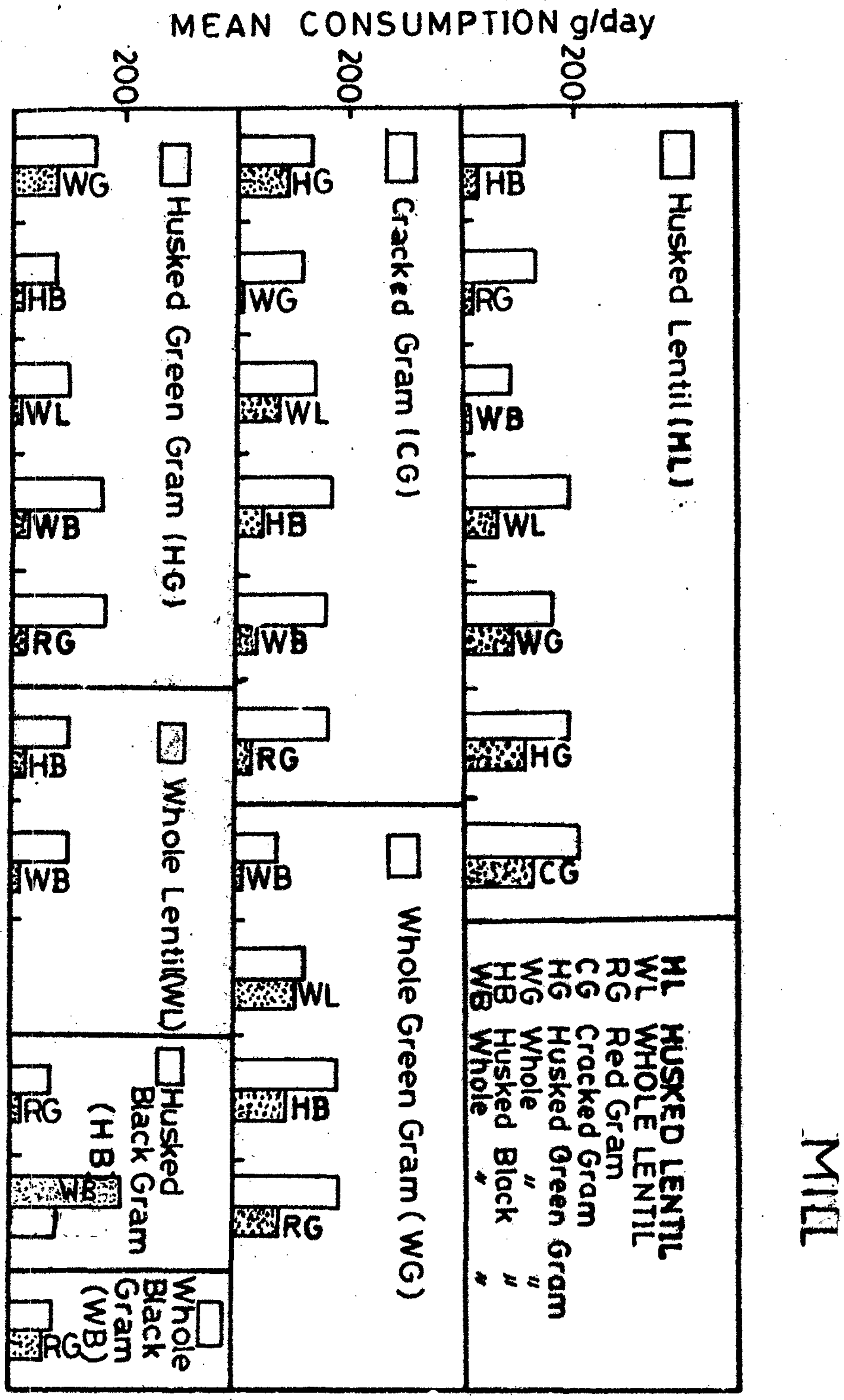
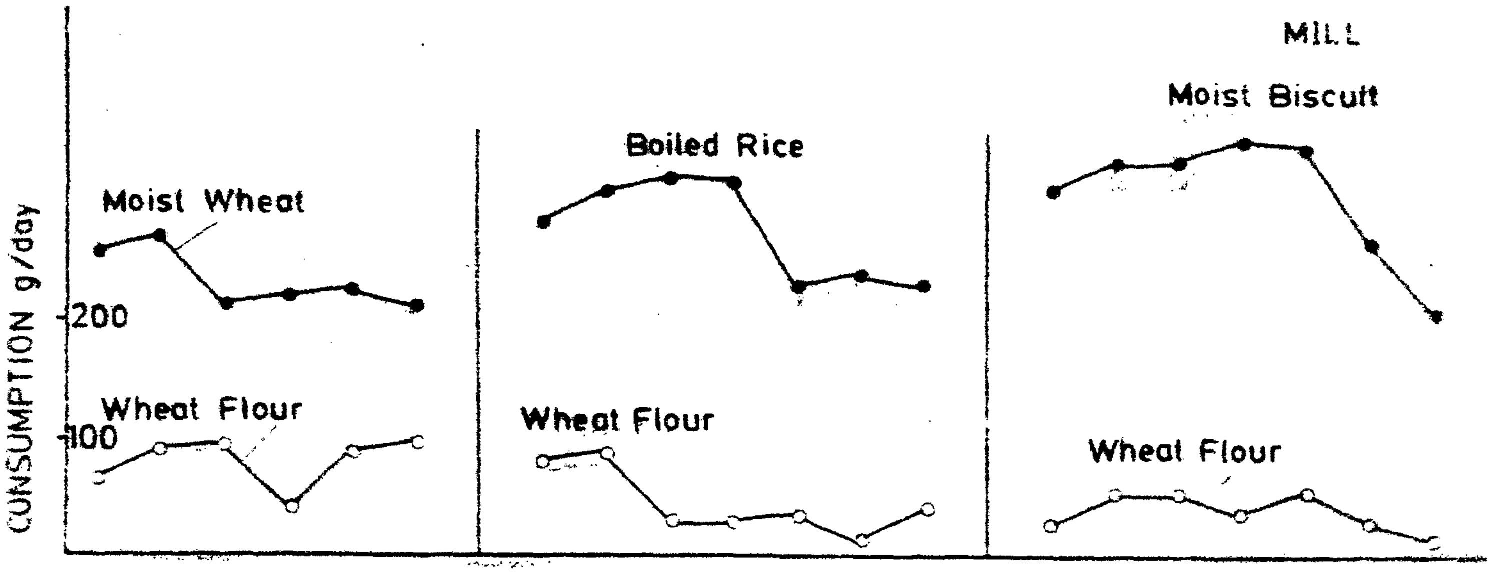

MEAN CONSUMPTION g/day
200
MILL
Husked Lentil (HL)
Cracked Gram (CG)
Husked Green Gram (HG)
Whole Lentil (WL)
Whole Green Gram (WG)
Husked Black Gram (HB)
Whole Black Gram (WB)
HL HUSKED LENTIL
WL WHOLE LENTIL
RG Red Gram
CG Cracked Gram
HG Husked Green Gram
WG Whole " "
HB Husked Black " "
WB Whole " "
HB RG WB WL WG HG CG

Fig. 15

Figure 16. Consumption of moist foods and dry alternative by mill rats.



MILL
CONSUMPTION g/day
200
100
Moist Wheat
Wheat Flour
Boiled Rice
Wheat Flour
Moist Biscuit
Wheat Flour

Fig. 16

Figure 17 : Barley was the only natural food present at fort, and it was preferred to all other kinds of whole cereals including millet.

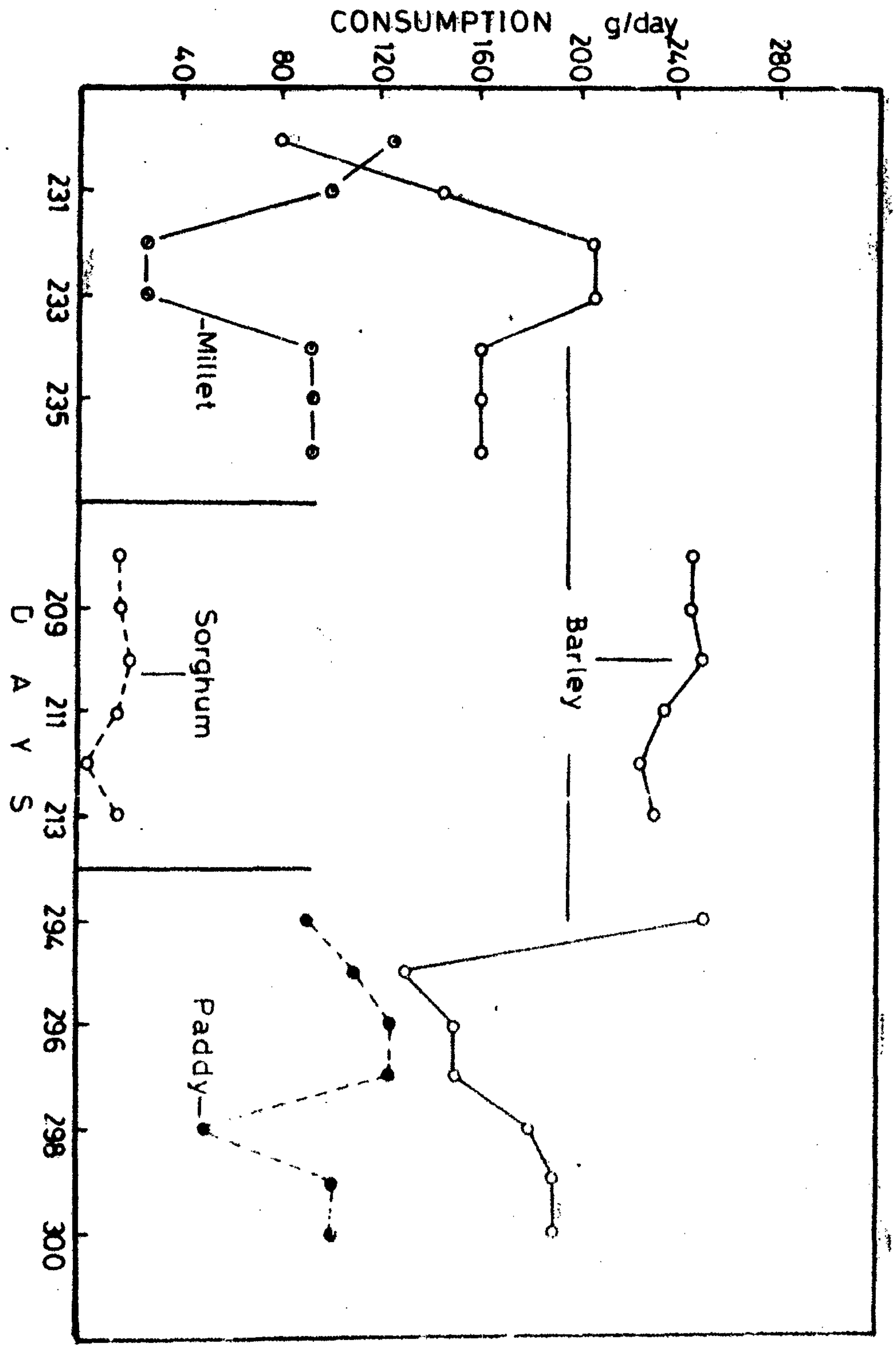
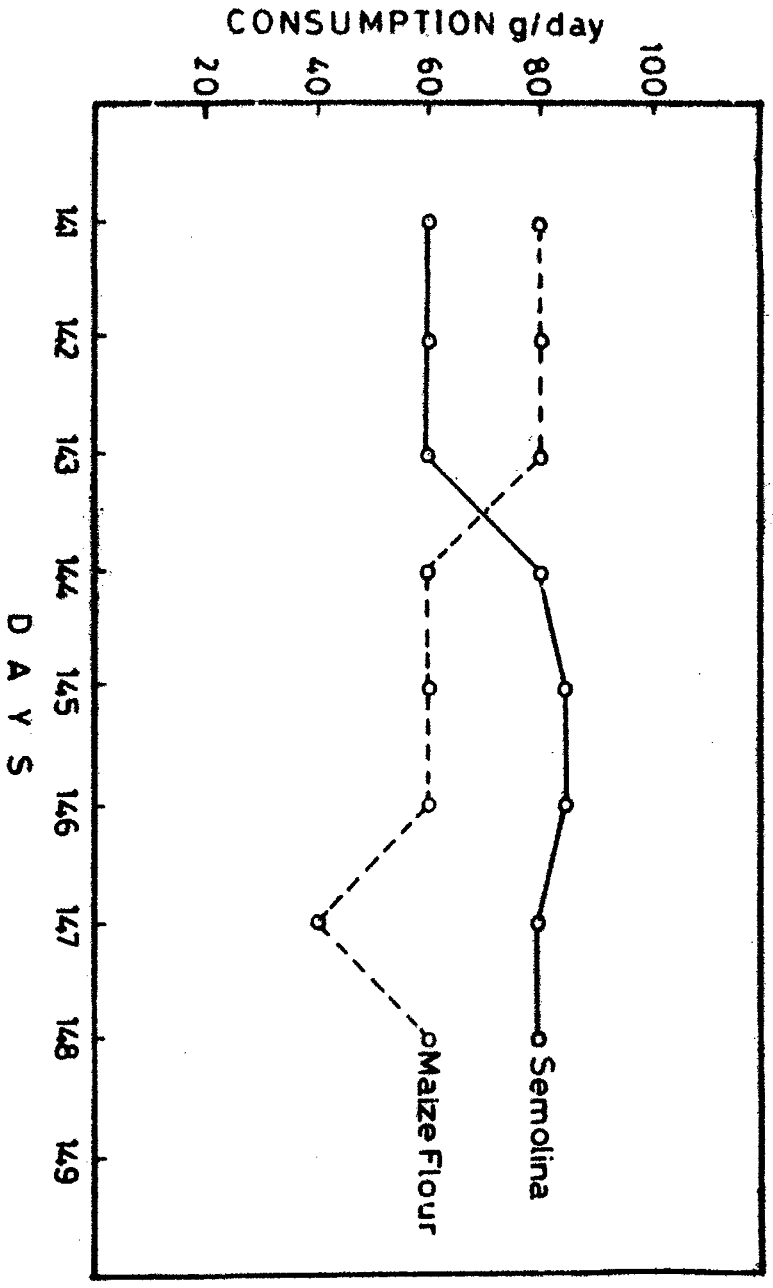

CONSUMPTION g/day
40
80
120
160
200
240
280
231
233
235
209
211
213
294
296
298
300
D A Y S
Millet
Sorghum
Barley
Paddy

Fig 17

Figure 18 : The figure shows the intake of semolina as compared to maize flour by the fort rats. Maize flour was initially preferred by the rats.



CONSUMPTION g/day
20
40
60
80
100
141
142
143
144
145
146
147
148
149
DAYS
Semolina
Maize Flour

Fig. 18

Figure 19 : Consumption of whole millet, millet flour and lentil by the fort rats in a three choice test. The choice alternated between the textural form of the cereal, but ground form was eventually preferred. Lentil was not eaten in large amounts than the flour on any day of the tests.

In the choice between whole wheat and wheat flour, the grains were eaten initially in large amounts.

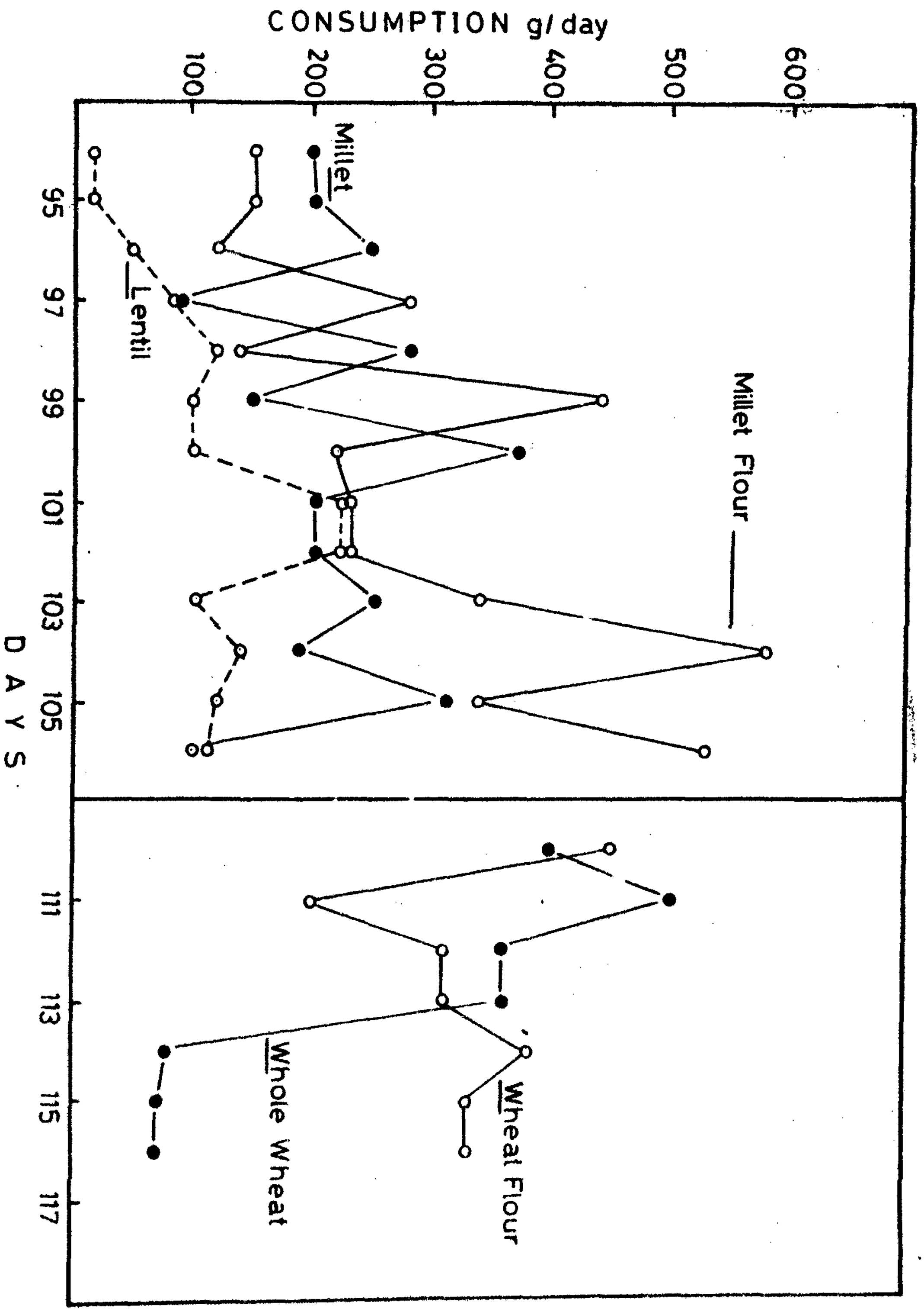

CONSUMPTION g/day
100
200
300
400
500
600
Millet
Lentil
Millet Flour
Wheat Flour
Whole Wheat
95
97
99
101
103
105
111
113
115
117
DAYS

Fig. 19

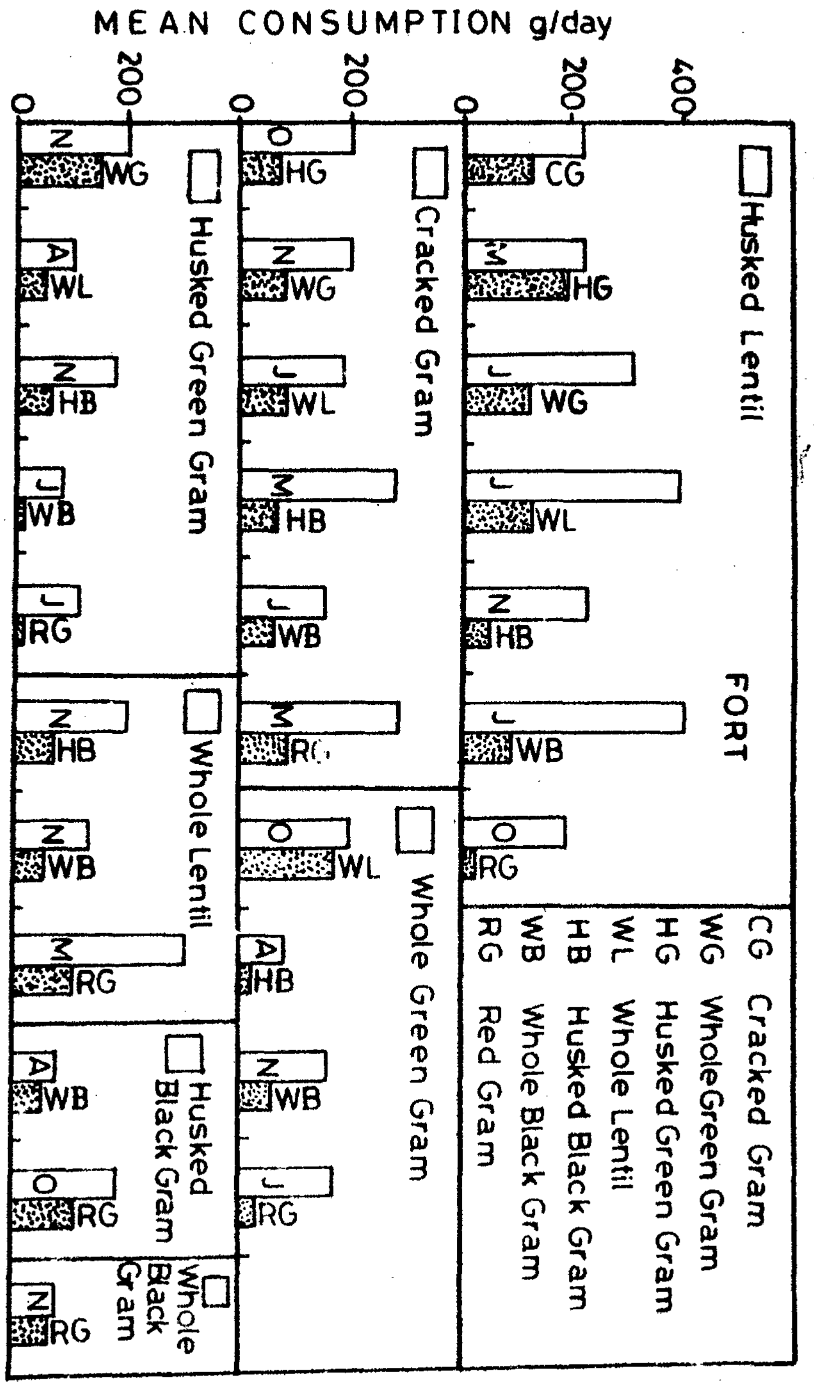

MEAN CONSUMPTION g/day
0
200
400
Husked Lentil
Cracked Gram
Husked Green Gram
Whole Green Gram
Whole Lentil
Husked Black Gram
Whole Black Gram
FORT
CG Cracked Gram
WG Whole Green Gram
HG Husked Green Gram
WL Whole Lentil
HB Husked Black Gram
WB Whole Black Gram
RG Red Gram

Fig. 20

Figure 21 : The relative amount of moist and dry foods eaten by fort rats.

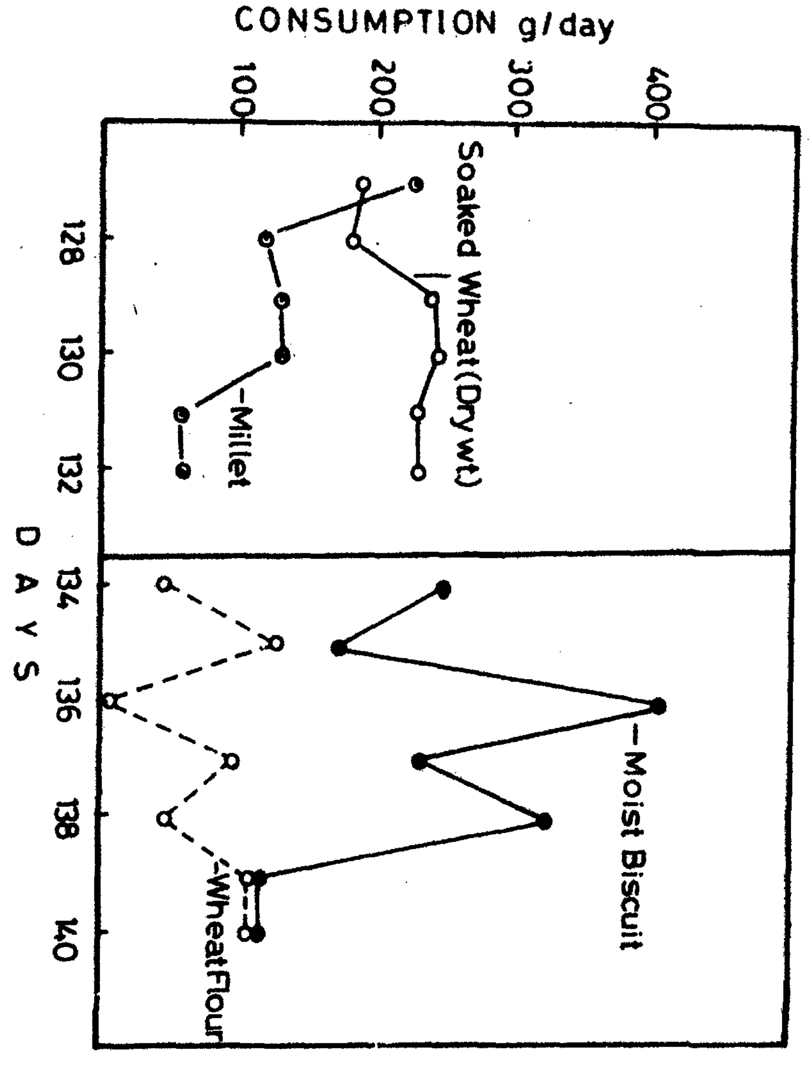

CONSUMPTION g/day
100
200
300
400
Soaked Wheat (Dry wt.)
-Millet
-Moist Biscuit
-WheatFlour
128
130
132
134
136
138
140
D A Y S

Fig. 21

Figure 22 : *Consumption of maize flour as compared to maize flour + sugar at fort. Both the foods were eaten in equivalent amounts by the rats on many days of the test.*

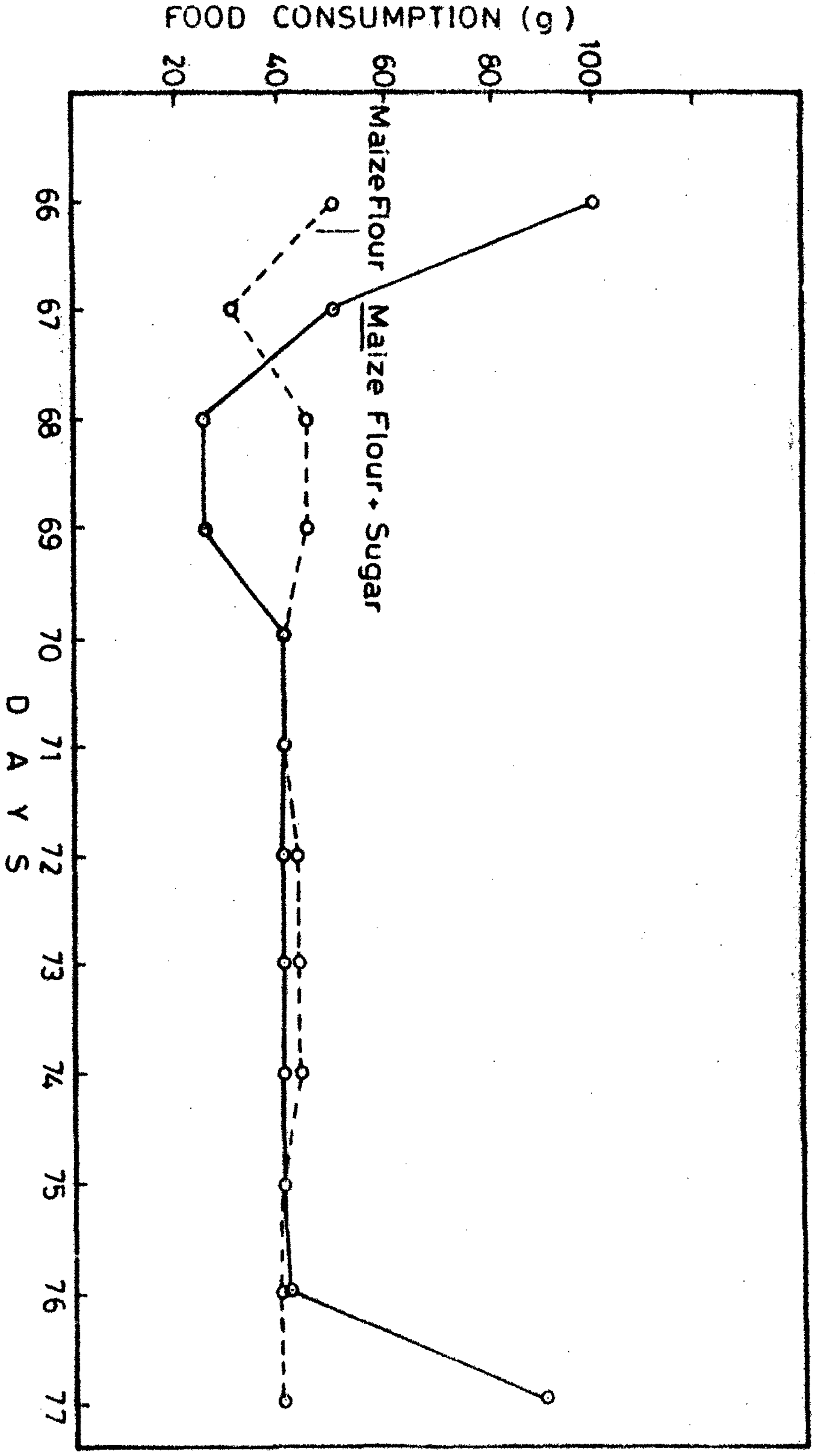

FOOD CONSUMPTION (g)
20
40
60
80
100
Maize Flour
Maize Flour + Sugar
66
67
68
69
70
71
72
73
74
75
76
77
D A Y S

Fig. 22

Figure 23 : *The figure shows the daily consumption of oily foods as compared to plain cereal equivalent. The oily mixture was eaten by the rats in much larger amounts on all days of the test.*

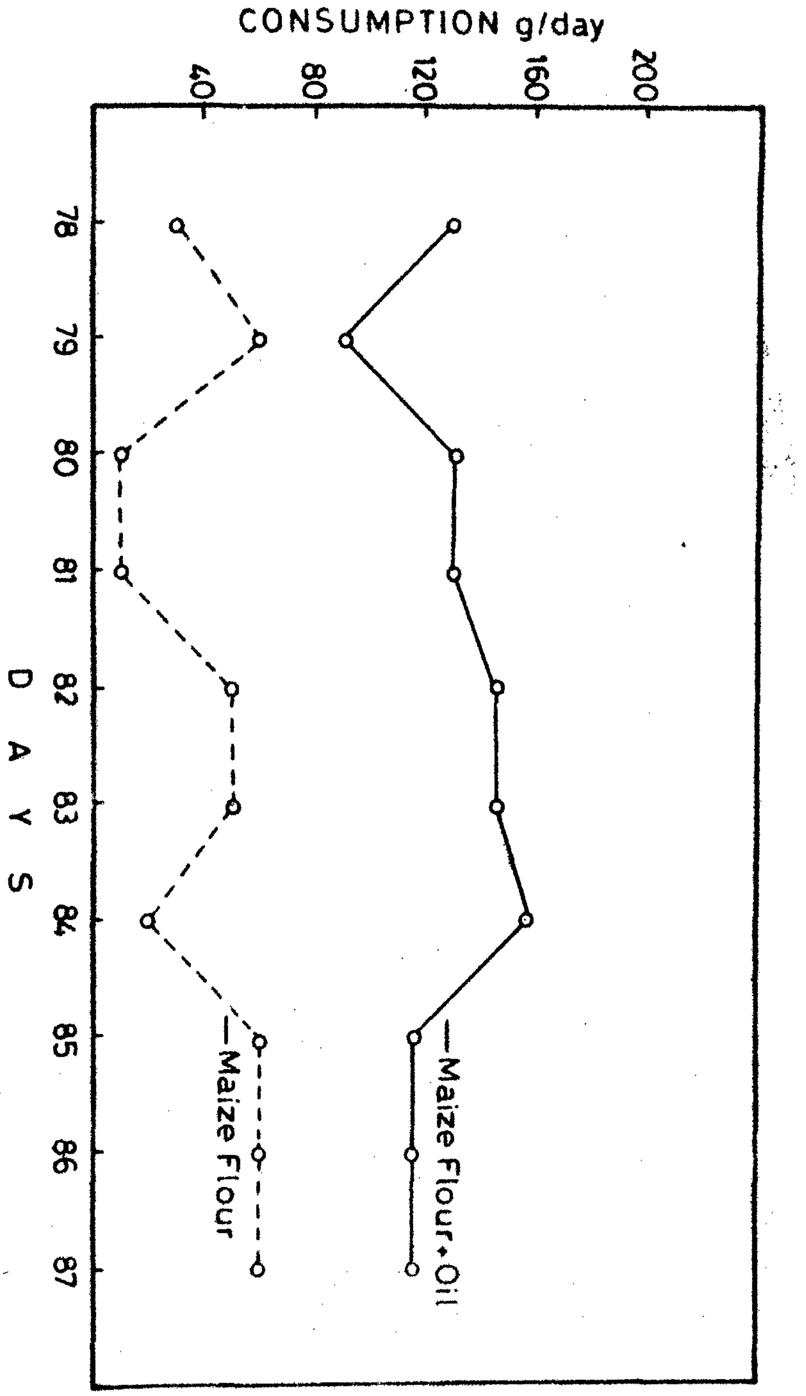

CONSUMPTION g/day
40
80
120
160
200
78
79
80
81
82
83
84
85
86
87
D A Y S
—Maize Flour+Oil
—Maize Flour

Fig. 23

Figure 24 : The amount of oily and sugar mixture consumed by the rats at fort. The sugar mixture was eaten in larger amounts on 2 days of the test.

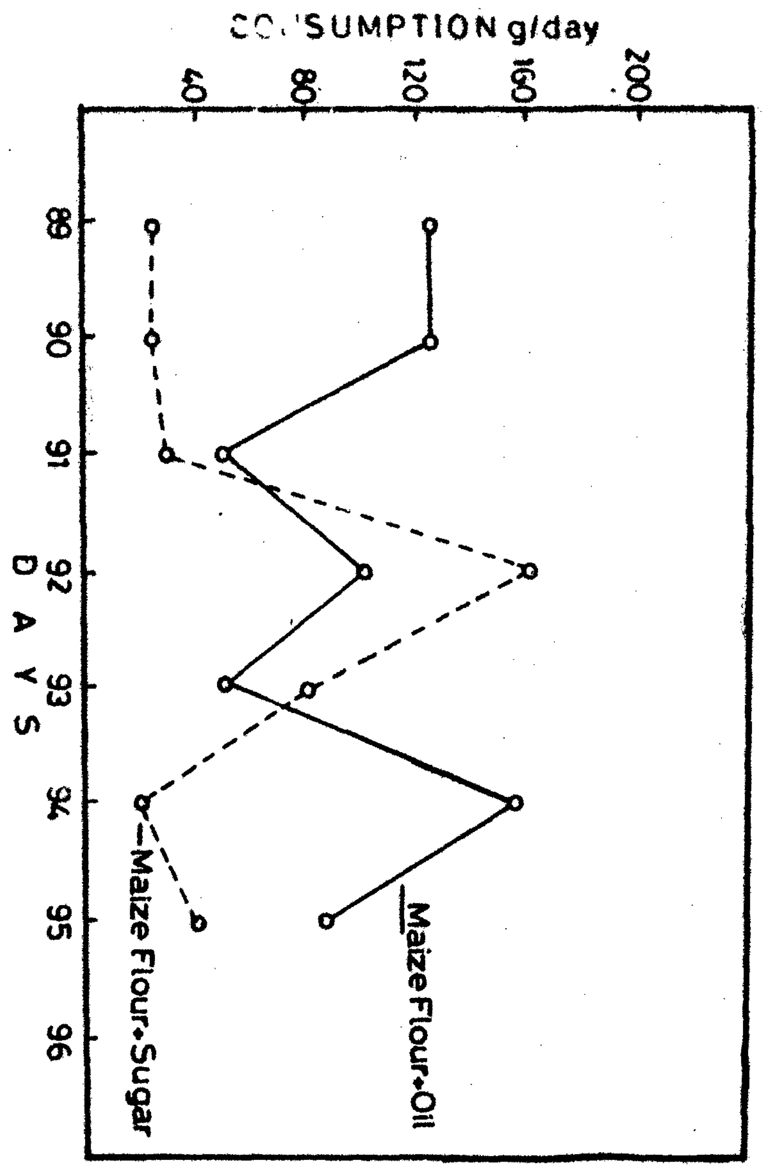

CONSUMPTION g/day
40
80
120
160
200
D A Y S
89
90
91
92
93
94
95
96
Maize Flour+Oil
Maize Flour+Sugar

Fig. 24

Figure 25 : Weekly mean intake of baits by the fort rats, calculated from the month of February to December. The large difference in intakes over a long period are thus highlighted.

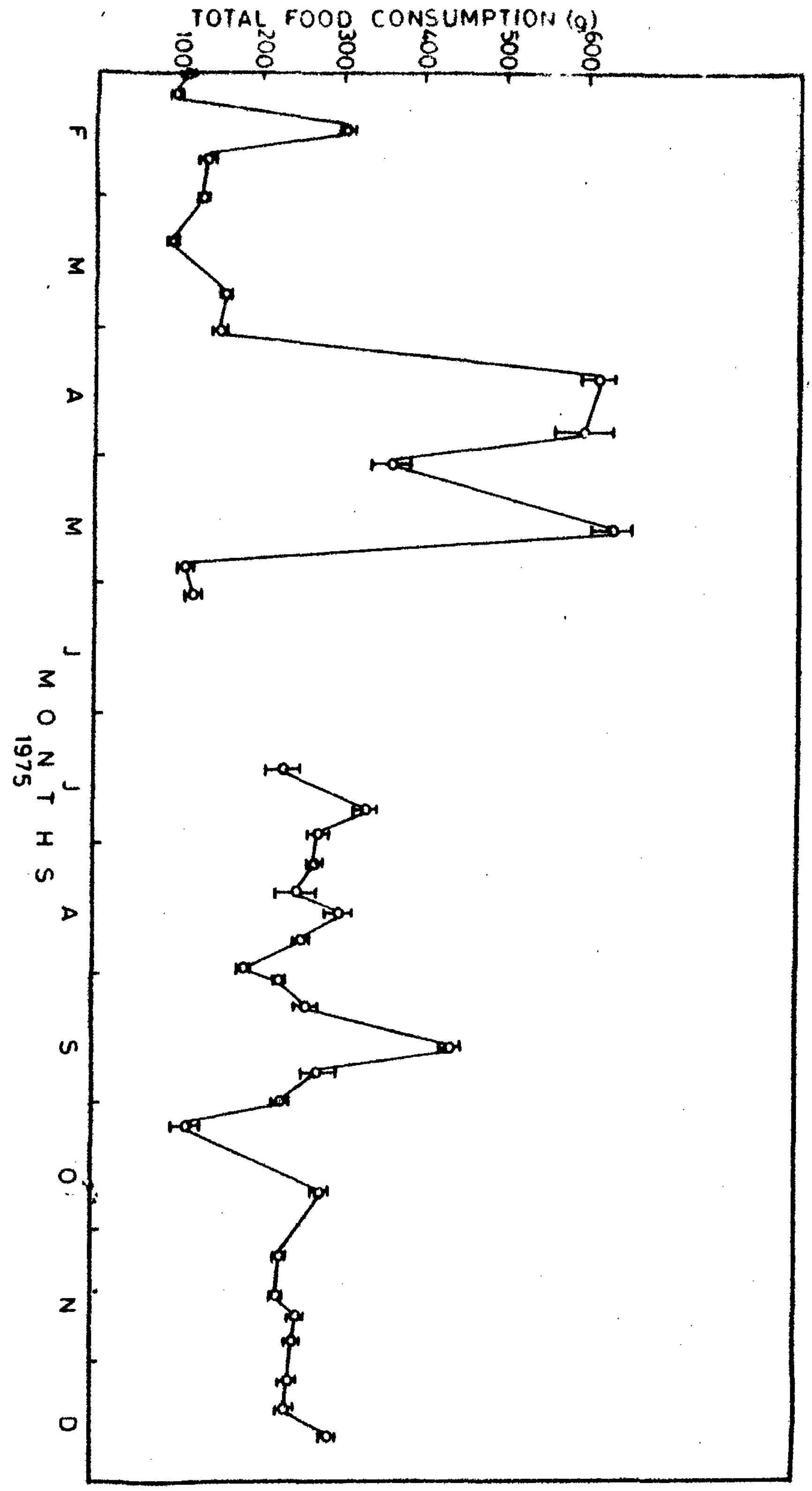

TOTAL FOOD CONSUMPTION (g)
100
200
300
400
500
600
F
M
A
M
J
J
A
S
O
N
D
MONTHS
1975

Fig. 25

Figure 26 : *The figure shows the rat numbers estimated from food consumption data obtained at the farm building at fort. The maximum levels in population are reached in April, while minor peaks occur in July, August and September. During each of these periods rats pups are also recovered.*

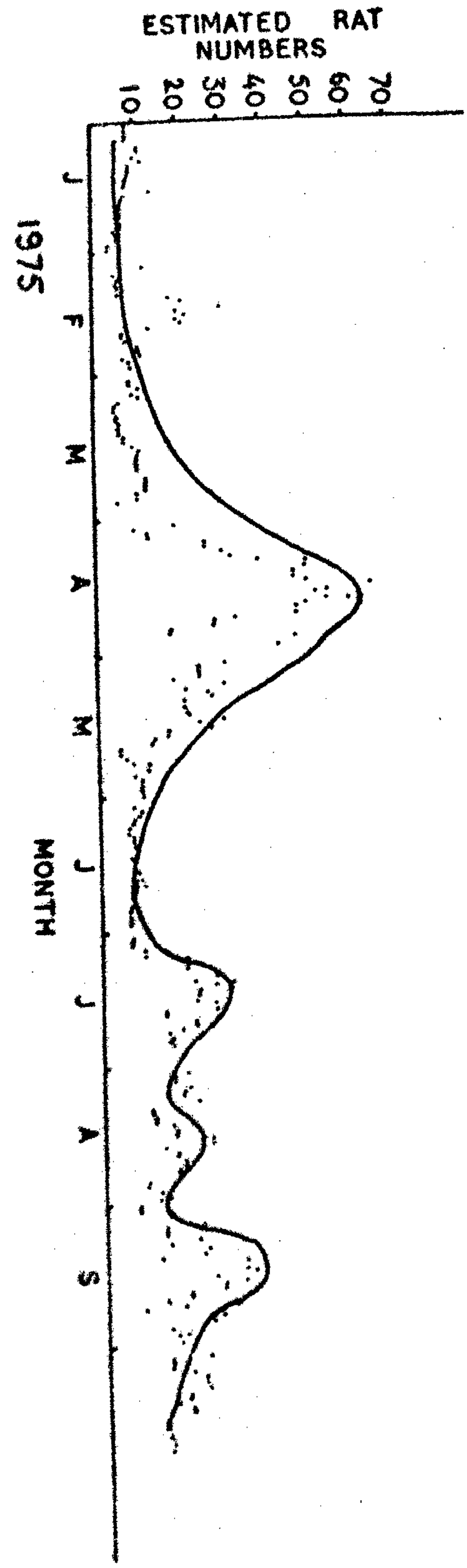

ESTIMATED RAT NUMBERS
10
20
30
40
50
60
70
1975
J
F
M
A
M
J
J
A
S
MONTH

Fig. 26

EFFECT OF TEXTURE OF FOOD ON BAIT-SHY BEHAVIOUR IN WILD RATS (RATTUS RATTUS)

INTRODUCTION

Wild rats, Rattus norvegicus Berk. and R. rattus L., discriminate between a wide variety of foods by their distinctive tastes and textures (Barnett and Spencer, 1953 ; Khan, 1974). Laboratory rats (and presumably the wild type also) even have some capacity to choose the better of alternative foods (Barnett, 1975). The obverse of this dietary self-selection is "bait-shyness" or the avoidance of toxic foods (Armour and Barnett, 1950; Rozin and Kalat, 1971).

Foods mixed with poison are also discriminated against on the basis of taste (Barnett et al., 1975) and then avoided, even when offered without poison (Prakash and Jain, 1971). One question of practical importance, still to be examined, concerns the development of shyness to textural variants of the same food (e.g. grains in various states of division). If textural variation is not important, then aversion developed for, say, wheat flour would also result in the avoidance of whole wheat.

The present experiments examined the responses of bait-shy rats to changes in the state of division of baits on which they were fed.

METHODS

Subjects were wild-caught stock, acclimatised to laboratory conditions and living in stable colonies. At the time of the experiments, pregnant females and juveniles ($<$80 g in weight) were excluded, and the adults left in colonies as before. Sex and body-weight of individuals in different colonies are given in Table 13.

Housing consisted of wire-mesh cages, 1.12 X 1.0 X 0.32 m, or tanks, 2.7 X 1.5 X 1.2 m. When not under test, rats were maintained on a standard laboratory diet for rats, as earlier. Water was provided *ad libitum* and cabbage once a week.

Millet (*Pennisetum typhoides* Burm), wheat (*Triticum aestivum* L.), lentil (*Lens esculenta* Moench) and gram (*Cicer arienatum* L.,), and their unextracted flours, were used as test foods. Weighed amounts were presented in dissection trays (26 X 30 X 8 cm.); the residue, including that spilled, was weighed the next day.

In experiments 1 and 2, rats were offered a choice of millet and wheat grains, and then of millet and wheat flours, each for 8 days. After this, zinc phosphide (4 mg/10 g of food) was added to the millet flour in

Experiment 1, and to the wheat flour in Experiment 2. The poisoned food and the harmless alternatives — wheat flour (Experiment 1) and millet flour (Experiment 2) were continuously available during the next 11 days. After that millet and wheat, in both forms, were presented again for 8 days each and in the same order as before. The schedule for the controls was identical except that no poison was added to any of the foods. Intake was recorded daily for the 43 days duration of each experiment.

The same procedure was followed in Experiments 3 and 4 except that husked, cracked lentil and gram replaced the cereal grains, and lentil and gram flours replaced the cereal flours.

Methods described by Bailey (1959) were followed for statistical analysis of the data.

RESULTS

Table 14 summarises the findings from only one colony of each experiment, as examples of typical results. The results of Experiments 1 and 3 are illustrated in Figs.27 and 28. In most experimental colonies, some of the rats died following the ingestion of poison. The experiments were, however, continued with the survivors.

SELECTION OF TEST FOODS

Millet is readily accepted by "black" or "roof" rats in preference to other grains (Khan, 1974). Rats of Experiment 1 also preferred millet or millet flour to wheat or wheat flour. Neither form of wheat was disfavoured, but the flour contributed more to mean daily intake than did the grain (Table 14).

In Experiment 2 millet was, however, only marginally more preferred than wheat (Table 14), and the rats clearly preferred wheat flour to millet flour. This may reflect their greater experience in the laboratory with wheat flour. Cracked lentil was favoured over cracked gram in Experiment 3, as also observed by Khan (1974). It was, however, even more preferred when offered as flour with the same form of gram (Table 14).

The rats of Experiment 4 behaved atypically by favouring cracked gram over lentil. Gram flour was, however, not chosen when compared to lentil flour (Table 14). This is exactly the opposite of what happens in the case of cereals, which are usually preferred in a fine state of division (Barnett, 1969; Khan, 1974).

The control rats selected the foods in the same order. This order of preference did not change when the *same foods were offered again.*

EFFECT OF POISONING

The rats, except in Experiment 4, were given poison in their preferred foods. Consequently, on Days 1 and 2 poisoned foods, e.g. millet flour in Experiment 1 (Fig.27) and lentil flour in Experiment 3 (Fig.28), were eaten in large amounts. On the following days, however, intake of poisoned foods was greatly reduced and that of harmless alternatives increased simultaneously. Similarly, gram flour in Experiment 4 became more aversive when mixed with zinc phosphide (Table 14). This change in feeding pattern, the obverse of that of controls (Table 14), was clear evidence of the avoidance of toxic foods.

FOOD PREFERENCES AFTER TREATMENT

When the choice tests were repeated, the rats rejected the foods to which poison had been added (bait-shyness), namely millet flour in Experiment 1, wheat flour in Experiment 2 and lentil flour in Experiment 3 (Table 14, Figs.27 and 28). Earlier, these foods had been readily accepted, as they still were in the controls (Table 14).

The survivors in Experiment 1, however, ate as much whole millet as they had before poisoning (Fig.27).

Similarly, rats of Experiment 2 accepted whole wheat while, unlike controls, avoiding wheat flour (Table 14). Poisoning in cereal flours, therefore, did not affect the preference for the corresponding whole grains (Table 14).

In Experiment 3, lentil flour and grain were both rejected after poisoning (Fig.28). Treatment with poison in flour evidently affected the preference for cracked, husked grain, unlike the results of Experiments 1 and 2. Similarly, poison in gram flour led to an increased consumption of lentils (Table 14), which were then preferred to cracked gram. The cont-rols, however, continued to accept cracked gram in preference to lentil (Table 14).

DISCUSSION

Zinc phosphide is a relatively slow acting poison and its mixtures,especially with such attractive foods as millet flour and lentil flour, are thus avoided only gradually, and never completely ignored (Figs.27 and 28). The foods in which zinc phosphide has been ingested are, afterwards consistently rejected, even when presented in a harmless form. The gerbils Meriones hurrianae Jerdon and Tatera indica Hardwicke, respond similarly to foods previously mixed with this poison (Prakash and Jain, 1971).

The specific tastes, by association with poisoning, apparently become the basis of avoidance.

In Experiments 1 and 2, treatment with zinc phosphide clearly resulted in a complete reversal of choice for cereal flours (Table 14; Fig.27). The rats, however, successfully discriminated between flour and whole grains, and poisoning in flour did not result in rejection of the corresponding grain. Possibly due to the presence of outer seed structures (pericarp and testa), the taste of grains is perceived distictly from flour. When pericarp and testa are absent, as in husked and cracked lentil and gram, poisoning in one form does affect the preference for another form of the same food (Table 14; Fig.28), or shyness is broadened to alternative forms. Thus, texture is also "sensed", and when the same food is offered in alternative forms, it is confounded with taste.

Present results indicate, therefore, that whole cereal and its corresponding flour can be used successively in poisoning operations during pest control. Pulses can be used likewise, as whole grains and then in the form of husked, cracked grains (Bhardwaj and Khan, 1978). Then, consecutive treatments with zinc phosphide would not result in any loss in efficacy of the second treatment due to bait-shyness. However, confirmation of this is needed for the much higher concentrations of zinc *phosphide (c. 50-500 mg/10 g of food) normally used in the field.*

SUMMARY

Colonies of wild rats, Rattus rattus L., were offered a choice between millet and wheat, or between cracked lentil and cracked gram. The foods were given first as grains and subsequently in the form of unextracted flours. The rats were then poisoned with zinc phosphide (4 mg/10 g of food) in one of the two flours and again presented with the same choice of unpoisoned foods in the same order as before.

The rats avoided the flours in which they had ingested poison (bait-shyness). In the case of lentil and gram, they also avoided the corresponding husked grain. However, when the rats were poisoned in cereal flour their preferences for one or other of the whole grains remained unaffected. Apparently whole millet and whole wheat were sufficiently different in taste or texture from their respective flours to prevent the rats associating the two. The results indicate the possibility of following such baiting schemes in order to eliminate shyness during control operations against this pest.

Table 13 : Weight (g) and sex of rats in the colonies, with record of deaths that occurred following treatment.

TABLE - 13

Exp. No.	Description of colony	Rats		Body weight (g ± S.E.)		Deaths
		Male	Female	Mean	Range	
1	Experimental	1	3	126 ± 3.12	119-131	119 g ♀
	Control	2	5	170 ±11.51	116-230	
2	Experimental	1	3	163 ± 5.64	160-190	-
	Control	-	2	125 ± 3.42	116-134	-
3	Experimental	3	15	169 ± 5.67	115-190	155 g ♀
	Control	1	7	168 ±15.0	92-226	178 g ♂
4	Experimental	2	14	142 ± 6.27	110-165	120 g ♀ 100 g ♂
	Control	2	6	143 + 2.25	130-152	-

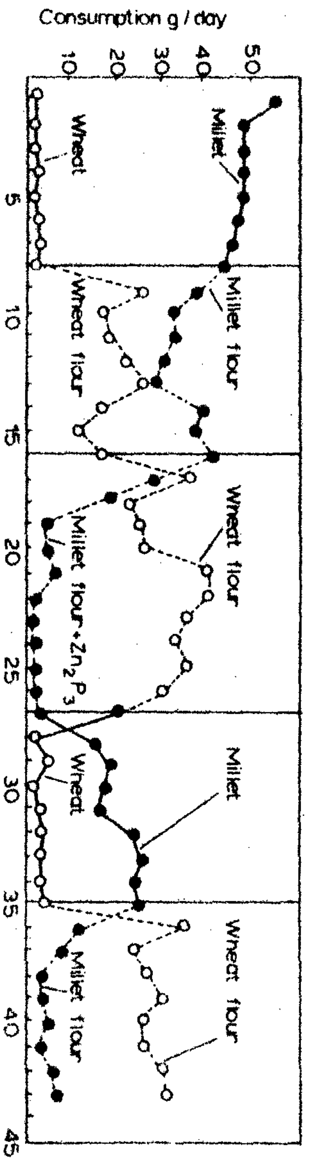
Table 14 : Consumption of foods (means + S.E.) presented to experimental rat groups.

TABLE - 14

Exp. No.	Length of test (days)	Mean consumption of foods offered (g/day ± S.E.)				% total consumption
1	8	Whole millet	47.92 ± 1.13	Whole wheat	1.7 ± 0.11	96;4
	8	Millet flour	37.53 ± 1.71	Wheat flour	19.13± 1.81	66;34
	11	Millet flour + poison	5.64 ± 3.00	Wheat flour	31.12± 2.63	14;86
	8	Whole millet	20.11 ± 1.53	Whole wheat	2.37± 0.35	90;10
	8	Millet flour	5.12 ± 1.30	Wheat flour	27.90± 1.40	16;84
Control	8	Whole millet	96.60 ± 6.70	Whole Wheat	8.20± 1.20	92;8
	19	Millet flour	68.30 ± 7.60	Wheat flour	36.60± 2.90	65;35
	8	Whole millet	67.00 ± 4.20	Whole wheat	6.60± 0.20	91;9
	8	Millet flour	61.80 ± 6.20	Wheat flour	31.00± 2.10	66;34
2	8	Whole wheat	22.00 ± 1.60	Whole millet	25.4 ± 3.20	47;53
	8	Wheat flour	32.80 ± 1.40	Millet flour	20.00± 5.40	61;39
	11	Wheat flour + poison	9.51 ± 0.66	Millet flour	30.21± 2.96	23;77
	8	Whole wheat	24.72 ± 3.54	Whole millet	8.56± 1.52	75;25
	8	Wheat flour	5.34 ± 1.32	Millet flour	35.56± 2.34	12;88
Control	8	Whole wheat	17.00 ± 1.27	Whole millet	27.00± 4.17	39;61
	19	Wheat flour	27.00 ± 1.27	Millet flour	11.15± 3.46	71;29
	8	Whole wheat	17.11 ± 1.21	Whole millet	13.11± 4.34	57;43
	8	Wheat flour	20.36 ± 1.25	Millet flour	7.16± 0.66	74;26

Exp. No.	Length of test (days)	Mean consumption of foods offered (g/day ± S.E.)				% total consumption
3	8	Cracked lentil	114.04 ± 2.55	Cracked gram	50. 6 ± 1.41	69;31
	8	Lentil flour	233.00 ± 9.96	Gram flour	27. 6 ± 4.40	90;10
	11	Lentil flour + poison	30.77 ± 18.31	Gram flour	103.77 ± 12.66	22;78
	8	Cracked lentil	16.63 ± 1.16	Cracked gram	101.75 ± 1.43	13;87
	8	Lentil flour	24.37 ± 3.66	Gram flour	93.75 ± 3.00	20;80
Control	8	Cracked lentil	64. 7 ± 9.56	Cracked gram	29.55 ± 2.60	69;31
	19	Lentil flour	93.81 ± 3.56	Gram flour	31.33 ± 2.27	75;25
	8	Cracked lentil	88.78 ± 4.28	Cracked gram	15.56 ± 3.18	85;15
	8	Lentil flour	98.17 ± 2.18	Gram flour	17.37 ± 3.00	85;15
4	8	Cracked gram	161.67 ± 10.82	Cracked lentil	81.44 ± 4.87	66;34
	8	Gram flour	78.00 ± 11.56	Lentil flour	152.55 ± 13.56	34;66
	11	Gram flour + poison	46.80 ± 4.55	Lentil flour	193.04 ± 4.90	20;80
	8	Cracked gram	91.22 ± 7.77	Cracked lentil	132.81 ± 7.15	40;60
	8	Gram flour	35.72 ± 3.21	Lentil flour	190.55 ± 5.13	16;84
Control	8	Cracked gram	72.44 ± 4.40	Cracked lentil	23.22 ± 3.51	76;24
	19	Gram flour	26.21 ± 4.32	Lentil flour	62.23 ± 6.71	30;70
	8	Cracked gram	70.23 ± 4.36	Cracked lentil	20.25 ± 2.26	78;22
	8	Gram flour	19.36 ± 1.88	Lentil flour	74.00 ± 3.36	21;79

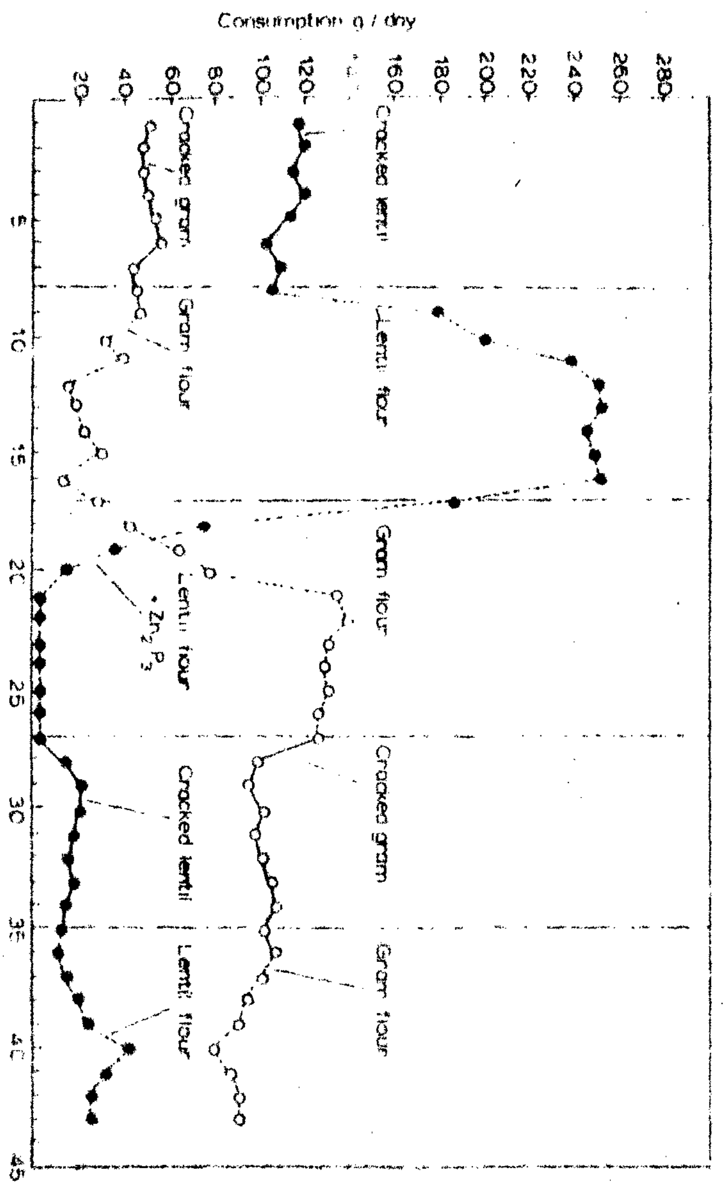
Fig.27. Experiment 1. Consumption by rats of whole cereal grains or of flours, with or without zinc phosphide, on successive days.



Consumption g / day
10
20
30
40
50
5
10
15
20
25
30
35
40
45
Millet
Wheat
Millet flour
Wheat flour
Wheat flour
Millet flour + Zn2P3
Millet
Wheat
Wheat flour
Millet flour

Fig. 27

Fig. 28. Experiment 3. Consumption by rats of cracked pulses or of flours, with or without zinc phosphide poison, on successive days.



Consumption g / day
Days
Cracked lentil
Cracked gram
Lentil flour
Gram flour
Gram flour
Lentil flour
Zn_2P_3
Cracked gram
Cracked lentil
Gram flour
Lentil flour

Fig. 28

EFFECT OF TEXTURE ON THE FOOD PREFERENCES OF BAIT-SHY WILD RATS (RATTUS RATTUS L.) II.

INTRODUCTION

The black rat is one among several species of wild rats, which rapidly learn to avoid eating a poisonous mixture (poison shyness; Barnett et al. 1975) and the particular foods used in it as base (bait-shyness). Thus rats surviving a poisoning campaign, may not accept the same poison or bait again (Barnett 1975). The study of this behaviour is important in our efforts to eradicate this pest (Chitty 1954).

The baits ordinarily used, cereals or pulses, are available in several forms—whole grains, husked grains, husked and cracked grains and flours in various states of division. There is evidence that cereals have distinctive tastes as grain and flour, and poisoning in cereal flours does not affect the preference of bait-shy rats for respective whole grains.

In our present study, such alteration of taste with texture was examined in the case of two pulses, lentil (Lens esculenta Moench) and green gram (Phaseolus aureus Roxb.). The rats were poisoned with zinc *phosphide in moist whole grains, and then their responses to moist whole and husked forms of the two pulses have been measured.*

MATERIALS AND METHODS

Bisexual group of black rats, R. rattus, trapped from Aligarh city, were housed in four wire-mesh cages, 1.12 X 1.0 X 0.32 m, with empty tins and straw for nesting. Water was provided ad lib.

When the experiments started the first experimental group (N=6) weighed 115.0 ± S.E. 14.3g (range: 80-160g), and the control group (N=5) 117.0 ± S.E. 8.1g (100-140g). In experiment 2, the mean weight of the experimental colony (N=6) was 100 ± S.E. 8.8g (82-130g), and the control (N=5) 96.0 ± S.E. 4.3g (82-105g).

Commercial varieties of lentil (L.esculenta), green gram (P.aureus) and black gram (P.mungo Roxb.) in two forms viz. whole grains and husked, cracked grains, were used as test foods.

Weighed amounts of food soaked in water for 24 hrs, drained on wiregauze for 2 hr and weighed again, were presented to the rat colonies. The residue, including spillage, was dried at 80^{o} C for 24 hr and then weighed (Rw). Equivalent amounts of pulses, as controls, were similarly soaked, drained, weighed and then dried for 24 hr and weighed again (Cw). Consumption of each pulse in terms of dry weight was calculated by subtracting from the weight of control the weight of residue each day. The weight of a pulse was nearly doubled on soaking, but there was little variation in dry weights.

Experimental Procedure:

In experiment 1, the rats were offered the choice between husked lentil and black gram for five days and in continuation whole lentil and black gram also for five days. Whole lentil mixed with zinc phosphide (0.02%, dry weight) and harmless black gram were given on the following six days. In the next 10 days, preference for husked lentil, husked black gram and whole lentil, whole black gram was tested again, each for five days. Control rats received the same foods, without the poison.

The same procedure was followed in experiment 2, except that the choice was between green gram and black gram. Treatment was given in whole green gram. Controls were also run, as in experiment 1.

The choice shown by the experimental rats for each form of the two pulses before and after treatment was compared to choice shown for equivalent forms by the controls. Student's 't' test (Bailey 1959) was used for testing the significance of preferences observed.

RESULTS

Some of the rats died during treatment, 160g ♀ & 150g ♀ in experiment 1 and 130g ♀ & 81g ♀ in experiment 2, but the experiments were continued with survivors. The results are given in Table 15. Similar results obtained from other colonies which were greatly decimated by the poison, are not reported here.

In experiment 1, before the poison was presented, husked or whole lentil was preferred to husked or whole black gram (Table 15). Similarly, husked or whole green gram was selected when compared to the two forms of black gram (Table 15). Controls also preferred lentil to black gram (mean daily intake; 211.6 ± 11.7g husked lentil, 104 + 2.1g husked black gram; 229.5 ± 11.7g whole lentil, 85.8 ± 7.3g whole black gram) and green gram to black gram (mean daily intake; 211.6 ± 1.6g husked green gram, 103 ± 6.1g husked black gram; 235 ± 14.4g whole green gram, 82.4 ± 9.0g whole black gram).

The whole lentil and green gram were rejected when *mixed with zinc phosphide but the consumption of poisonous mixtures was reduced only gradually and that of harmless black gram increased simultaneously (Table 15). Thus, during poison treatment the choice in experimental groups became obverse to that observed for harmless equivalents in controls (mean daily intake: 239 ± 4.5g whole lentil, 59.0 ± 5.7g whole black gram; 236.0 ± 4.0g whole green gram, 70.5 + 12.5g whole black gram).*

When the pulses were presented again after treatment, but without poison, the whole lentil was consistently avoided in experiment 1 and similarly the whole green gram in experiment 2; and the whole black gram was mainly eaten in both experiments (Table 15). In controls, the rats persisted with eating more lentil or green gram rather than black gram (mean daily intake: 215.0 ± 15.1g whole lentil, 13.0 ± 2.4g black gram; 137.5 ± 7.5g whole green gram, 15.0 ± 1.0g black gram). Thus rats of both experiments 1 and 2 did not again prefer the foods in which they were poisoned.

In both experiments, however, husked lentil and husked green gram continued to be preferred to husked black gram (Table 15), much like the controls which also showed the same preference as before (mean daily intake; 140.0 ± 24.5g husked lentil, 18.6 ± 6.0g husked black gram; 161.6 ± 20.0g husked green gram, 30.6g husked *black gram). This was in contrast to the avoidance response shown by the experimental groups to whole lentil or green gram after treatment (Table 15).*

DISCUSSION

Exposure to poisoned lentil or green gram led to some deaths, clearly due to its ingestion in large amounts. Consumption of poisoned foods was then reduced by the survivors, though it was not stopped completely (Table 15). The avoidance obviously followed the development of 'poison-shyness' to zinc phosphide, while continued sampling of its mixtures may have been the result of the delayed action of poison (Barnett et al 1975). Zinc phosphide is a relatively slo-acting poison and the response induced by it is not comparable to that obtained with compounds which act quickly, like apomorphine sulfate, and bring about total avoidance in similar situations (Garcia et al, 1974).

Following treatment, the rats also became 'bait-shy', or averse to eating the particular foods in which they were poisoned, whole lentil in experiment 1 and whole green gram in experiment 2 (Table 15). Several species of rodents, including the gerbils Meriones hurrianae and Tatera indica (Prakash and Jain 1971) similarly respond to foods treated with zinc phosphide. Our rats, however, did not avoid the alternative forms of the same foods, i.e. husked lentil in experiment 1 and husked green gram in experiment 2 (Table 15).

If taste was the basis for such avoidance (Barnett et al. 1975; Garcia et al. 1974) then the taste of whole lentil or green gram was obviously distinct from that perceived in husked lentil or green gram. Thus two forms of the same pulse were treated as two different kinds of foods and poisoning in one form (whole grains), therefore, did not affect the preference of the rats to the other form (husked grain). Perhaps the outer seed structures (pericarp and testa) are responsible for such alteration of taste with texture in the case of whole grains which contained them as compared to husked grains, which are devoid of them (Khan 1974). Something very similar has also been observed in case of cereals.

SUMMARY

Black rats, *Rattus rattus* L., poisoned with 0.02% zinc phosphide in whole lentil (*Lens esculenta*) or green gram (*Phaseolus aureus*) did not accept their whole grains again (bait-shyness). No similar aversion was, however, shown to husked grains of lentil or green gram.

Apparently alternative textural states of the two pulses have distinctive tastes, and hence poisoning in one form (whole grains) does not affect the preference for the other form (husked grains). It is thus possible to avoid 'bait-shyness' by using whole and then husked grains of such pulses for poisoning this pest.

Table 15. Consumption by two groups of rats of husked and whole pulses before and after treatment with zinc phosphide in whole pulses.

TABLE-15

Expt. No.	Length of test (Days)	Foods offered	Mean daily consumption g/day ± S.E.	% Total consumption
1	5	Husked lentil; Husked black gram	198.0 ± 5.0; 60.5 ± 3.7	77; 23
	5	Whole lentil; whole black gram	213.3 ± 1.7; 109.6 ± 3.2	66; 34
	6	Whole lentil + Poison; whole black gram	45.4 ± 33.0; 119.8 ± 7.5	27; 73
	5	Husked lentil; Husked black gram	113.5 ± 15.0; 22.3 ± 5.4	84; 16
	5	Whole lentil; whole black gram	20.5 ± 3.7; 66.0 ± 5.0	23; 77
2	5	Husked green gram; Husked black gram	201.5 ± 6.0; 66.5 ± 6.4	76; 24
	5	Whole green gram; whole black gram	211.6 ± 1.6; 107.6 ± 3.7	67; 33
	6	Whole green gram + Poison; whole black gram	42.0 ± 31.2; 124.4 ± 9.3	24; 76
	5	Husked green gram; Husked black gram	114.3 ± 13.3; 27.3 ± 3.7	81; 19
	5	Whole green gram; Whole black gram	14.5 ± 0.71; 116.0 ± 14.0	10; 90

RESPONSES OF ROOF RAT, RATTUS RATTUS L., TO NON-OILY AND OILY FOODS AFTER POISONING IN OILY FOODS

INTRODUCTION

Rattus rattus L. develop bait-shyness, or the avoidance of poisonous foods (Barnett 1975). The shyness appears for both poison and bait (Armour and Barnett 1950); which have to be changed in the field after every treatment (Barnett and Prakash 1975). Of the latter, mixtures of cereals and tasteless vegetable oils, e.g. of groundnut (*Arachis hypogea*), are widely used (Prakash 1976). Very little is, however, known about the choice of survivors, or bait-shy rats, to oily and non-oily foods. This was analysed by comparing the preferences of *R. rattus* for oily foods and plain cereal equivalents after poisoning in the former.

MATERIALS AND METHODS

The Rats: Subjects were wild-caught stock; fed and housed as described earlier.

. They were weighed and grouped into bisexual colonies; pregnant females and juveniles were excluded

The experiments conducted are termed I(for experiment 1) and II(for experiment 2), etc., throughout this paper. The colony selected for treatment had the mean weight of (i) 171.0 ± S.E. 10.82 g for I (N = 7), (ii) 150.12 ± S.E. 23.0 g for II (N = 3) and (iii) 123.71 ± S.E. 12.75 g for III (N = 3). The control colonies had mean weights of (i) 170.33 ± S.E. 7.54 g (N = 7), (ii) 107.0 ± S.E. 9.31 g (N = 4) and (iii) 110.11 ± S.E. 26.43 g (N = 3) respectively. Replicates were also run.

Test Foods: Unextracted flours of millet (*Pennisetum typhoides*), maize (*Zea mays*) and wheat (*Triticum aestivum*) were used as test foods. Groundnut oil was used in concentrations of 5%; and zinc phosphide, as poison at the rate of 0.04%. The weighed foods, two at a time, were given in metal containers; the residue, including spillage, was weighed the next day.

Experimental Procedure: In I, wheat flour was compared to millet flour and then to millet flour and oil in two consecutive tests of 8 days each. The rats were poisoned in oily food for 11 days. After this, oily and non-oily foods were again offered. In the former, maize flour and oil was also offered. The same procedure was followed in II and III except the choice between wheat flour and millet flour or millet flour and oil for (II) and maize flour or maize flour and oil for (III) was observed for 4 days each. Poison was given only for 8 days. Unlike I, no new oily food was offered after poisoning. Schedules for controls were similar, but they were not given any poison. Intake was recorded daily for 43 days (I) or 24 days (II & III).

Statistical Analysis: Significance of preferences observed was tested by paired t tests (Bailey 1959); and of changes in it by Mann-Whitney U test (Gibbons 1971).

RESULTS

Some rats died in I, but no deaths were observed in II and III, Results from only one colony of each experiment are, however, included in Table 16.

Selection of Test Foods (Non-oily Foods): Both millet and maize flours were preferred to wheat flour ($P < 0.05$; Table 16).

Oily Foods: Oily foods were similarly preferred ($P < 0.05$); millet or maize flour and oil were thus mainly eaten (Table 16).

A similar choice was observed in the controls (Table 16).

Effect of Poisoning in Oily Foods: The consumption of *poisonous millet or maize flour and oil declined on the first day. The avoidance became more obvious on the following days (U tests; $P < 0.05$). The rats changed over to eating harmless wheat flour, or the choice was reversed (Table 16).*

__Preference Observed After Poisoning:__

__Non-oily Foods:__ Millet flour in I and II, and maize flour in III, were again preferred to wheat flour, except on the day after poisoning ($P < 0.05$). Unlike in controls, however, both the cereals were now consumed in smaller amounts compared to that observed before poisoning (Table 16). Wheat flour was consumed in larger amounts (Table 16). Non-oily foods were avoided, but only partially.

__Oily Foods:__ In the following tests, however, the rats showed clear bait-shyness, rejecting the foods in which they had ingested poison, namely, millet flour and oil in I and II and maize flour and oil in III(Table 16). Earlier the same foods had been greatly favoured, as they still were in the controls (Table 16).

Although millet flour and oil was rejected in I; maize flour and oil was much preferred to wheat flour ($P < 0.05$: Table 16).

DISCUSSION

Dry or moist bait mixed with 0.04% zinc phosphide are avoided only gradually by the rats, R. rattus . Avoidance developed rapidly, however, when this poison was given in oily foods (Table 16). Perhaps zinc phosphide was easily ingested and took immediate effect when given in these baits because of the adhesiveness of oil. Thus, the behaviour (poison-shyness) is also influenced by the nature of bait employed.

Poisoning with oil also affected the responses to baits offered subsequently. Shyness developed for oily mixtures (bait-shyness) was not exactly broadened to corresponding cereal bases; and both millet and maize flours were avoided only partially by the bait-shy rats (Table 16). It would seem that such discriminations between oily and non-oily foods were made on the basis of their distinctive tastes (Barnett et al. 1975). It seems, however, more likely that there is only a difference in the strength of taste perceived in the alternative forms.

Thus, groundnut oil has no flavour and at best a neutral taste (Barnett 1969). This is also confirmed by the results of I as maize flour and oil (and not millet *flour and oil) was preferred by the rats after poisoning in millet flour and oil (Table 16). However, cereal flour have strong and distinctive tastes (Khan 1974). In human beings, however, taste effectiveness of sweet substances is reduced in the presence of non-sweet stimuli (Cameron 1947). Something similar may have occurred in our experiments:and the neutral groundnut oil exerted some masking effect on the taste of cereal bases.*

It is, therefore, obvious that bait-shyness developed by R. rattus can be reduced, but not eliminated, by poisoning them in cereals with groundnut oil and then in the same baits without it.

SUMMARY

The rats, Rattus rattus L., rejected oily foods previously mixed with zinc phosphide; but cereal equivalents, or non-oily foods were avoided only partially. Groundnut oil, though of neutral flavour, also exerted thus some masking effect on the taste of cereal bases.

Table 16. Consumption of foods (means$\pm$S.E.) offered in rat colonies.

TABLE - 16

Expt. No.	Length of test (days)	Foods offered	Mean consumption g/day ± SE	% Total consumption
1	8	Millet flour	72.0 ± 7.8	70
		Wheat flour	30.3 ± 4.5	30
	8	Millet flour + Oil	71.7 ± 6.1	72
		Wheat flour	27.2 ± 5.4	28
	11	Millet flour + Oil + Poison	11.2 ± 4.6	11
		Wheat flour	93.7 ± 1.4	89
	8	Millet flour	53.8 ± 1.4	52
		Wheat flour	49.7 ± 4.2	48
	4	Maize flour + Oil	67.7 ± 7.8	66
		Wheat flour	34.9 ± 1.3	34
	4	Millet flour + Oil	41.7 ± 6.2	40
		Wheat flour	58.9 ± 7.2	60
Control	8	Millet flour	50.0 ± 9.0	82
		Wheat flour	11.0 ± 5.0	18
	19	Millet flour + Oil	86.3 ± 2.1	73
		Wheat flour	31.6 ± 1.8	27

Expt. No.	Length of test (days)	Foods offered	Mean consumption g/day $\pm$ SE	% Total consumption
	8	Millet flour	93.5 ± 6.1	69
		Wheat flour	41.3 ± 3.3	31
	8	Millet flour + Oil	72.0 ± 1.2	75
		Wheat flour	24.0 ± 6.0	25
2	4	Millet flour	32.2 ± 1.3	89
		Wheat flour	4.0 ± 1.5	11
	4	Millet flour + Oil	26.5 ± 0.8	90
		Wheat flour	3.0 ± 0.7	10
	8	Millet flour + Oil + poison	5.5 ± 4.5	25
		Wheat flour	15.0 ± 2.1	75
	4	Millet flour	15.7 ± 3.0	60
		Wheat flour	10.5 ± 0.9	40
	4	Millet flour + Oil	11.0 ± 1.2	36
		Wheat flour	20.0 ± 0.8	64

Expt. No.	Length of test (days)	Foods offered	Mean consumption g/day ± SE	% Total consumption
Control	4	Millet flour	33.0 ± 1.3	92
		Wheat flour	2.0 ± 1.1	8
	12	Millet flour + Oil	26.5 ± 1.5	84
		Wheat flour	5.0 ± 1.2	16
	4	Millet flour	23.5 ± 0.6	78
		Wheat flour	6.7 ± 1.3	22
	4	Millet flour + Oil	31.5 ± 1.8	87
		Wheat flour	4.5 ± 0.5	13
3	4	Maize flour	31.2 ± 4.7	74
		Wheat flour	11.2 ± 2.5	26
	4	Maize flour + Oil	30.5 ± 1.5	85
		Wheat flour	5.5 ± 0.6	15
	8	Maize flour + Oil + Poison	5.3 ± 2.5	21
		Wheat flour	19.3 ± 1.2	79

Expt. No.	Length of test (days)	Foods offered	Mean consumption g/day ± SE	% Total consumption
	4	Maize flour	22.0 ± 4.0	53
		Wheat flour	19.5 ± 2.1	47
	4	Maize flour + Oil	15.5 ± 0.6	36
		Wheat flour	28.0 ± 1.2	64
Control	4	Maize flour	24.5 ± 1.3	68
		Wheat flour	11.7 ± 1.1	32
	12	Maize flour + Oil	27.5 ± 1.5	72
		Wheat flour	10.7 ± 0.5	28
	4	Maize flour	26.5 ± 1.2	71
		Wheat flour	10.3 ± 0.51	29
	4	Maize flour + Oil	26.0 ± 1.8	75
		Wheat flour	8.7 ± 0.7	25

C H A P T E R - IX

RESPONSES OF RATTUS RATTUS L., TO FOODS PREVIOUSLY USED IN A MIXTURE FOR POISONING WITH ZINC PHOSPHIDE

INTRODUCTION

Roof rats, Rattus rattus L. are one of the several species of wild rats that rapidly learn to avoid eating a poisonous mixture and then the particular food used in it as base, or become bait-shy. This behaviour has survival value, but is not advantageous . During control operations against this pest, a change in baits and poisons is thus needed after ever treatment (Barnett and Prakash 1975). However, the effects of poisoning rats in mixture of foods, rather than in one particular food, have not been examined. If no shyness develops for individual components, mixtures can be used to obtain additional poisoning before each food is tried separately as base for treatment. If the obverse is true, one poisoning will make several foods ineffective and the use of such baits (Barnett and Prakash 1975), may have to be discouraged. The present study reports the responses of bait-shy rats R. rattus towards each component of cereal mixtures on which they were fed.

MATERIAL AND METHODS

Wild-caught subjects were grouped into colonies and housed in wire-mesh cages, 1.32 X 1.0 X 0.32 m, with wooden boxes and straw for nesting. They were fed before tests on a laboratory rat diet. Water was given ad lib. Description of the colonies is given in Table 16.

Unextracted flours of millet (Pennisetum typhoides Burm), maize (Zeamays L.), wheat (Triticum aestivum L.), gram (Cicer arienatum L.), mixture of millet and maize flour (50 g + 50 g), and millet, maize and wheat flour (50 g each) were used as test foods. Weighed amounts were given in metal containers and the residue, including that spilled, was weighed the next day. The rats were poisoned in mixtures with zinc phosphide at the rate of 4 mg/10 g food.

In experiment 1, the rats were offered millet and maize flour mixture and wheat flour for 5 days. Zinc phosphide was then added to the mixture (4 mg/10 g food). This poisoned mixture and wheat flour were continuously available for the next 7 days. Thereafter, the choice offered consisted of harmless mixture and wheat flour, millet flour and wheat flour, and maize flour and wheat flour. Separate observation was made in tests of 3 days each and the food consumption was measured daily for

21 days.

The same procedure was followed in experiment 2. A mixture of millet, maize, wheat flour and gram flour was given for 5 days. The poisoned mixture with gram flour was given on the following 7 days. The harmless mixture as well as the millet, maize and wheat flour were separately compared to gram flour for 3 days each. Consumption was measured daily for 24 days.

Controls of the two experiments were given the same foods, but they were not given any poison. Replicates were also run simultaneously. The methods described by Bailey (1959) were followed for statistical analysis of results.

<u>RESULTS</u>

Results are summarised in Tables 17 and 18. Results of experiment 1 are also illustrated in figure 29. Some rats died following the ingestion of poisoned foods, but the experiments were continued with the survivors.

<u>Selection of Foods Before Poisoning:</u> The rats in experiment 1 preferred millet and maize flour mixture to wheat flour (paired t test, $P < 0.05$; Table 17), and those in experiment 2 preferred the millet, maize and wheat flour mixture to gram flour ($P < 0.05$; Table 19). A greater

preference was seen for mixtures in controls than in experimental groups but no significant difference was found in the total food consumption ($F_{5,5}$, $P > 0.05$).

Effect of Poisoning: When poison was added, consumption of mixtures was gradually reduced. Intake of harmless alternatives, wheat flour (experiment 1) and gram flour (experiment 2), was increased simultaneously (Table 18, 19; Fig.29). However, the rats continued to eat the poisoned foods in very small quantities. The choice of food in the experimental groups was thus reversed. The mixtures were still consistently preferred in the controls, as they were in the experimental groups before poisoning (Table 18, 19; Fig.29).

Food Preferences After Treatment: After poisoning, the rats in experiment 1 preferred wheat flour to the mixture of millet and maize flour, and to both millet or maize flour offered separately. The rats in experiment 2 similarly preferred gram flour as compared to the millet, maize and wheat flour mixture. Gram flour was also preferred to either of the three baits presented separately without poison. However, the mixtures and their components were preferred to the alternative wheat or gram flour by the respective controls.

DISCUSSION

The roof rat, R. rattus, prefers cereals to pulses; a linear order of choice is also shown between foods of either category, and both millet and maize flour are preferred to wheat flour (Khan 1974). Thus, superior foods added in a mixture also make more attractive baits than inferior foods offered alone (Table 18,19; Fig.29).

Even such attractive baits as cereal mixtures were avoided, though not completely ignored, on treatment with zinc phosphide (Table 18,19; Fig.29). The avoidance obviously followed the developemnt of poison-shyness to zinc phosphiae , while continued sampling of toxic baits indicated the slow aversive action of this poison . Interference by the learned-safety effect in poison-shyness was not evident (Rozin and Kalat 1971; Barnett et al. 1975).

After poisoning, the rats became averse to eating the mixtures, or 'bait-shy'. Shyness was also extended to components of the original baits (Table 18,19; Fig.29). If taste was the basis of such avoidance (Barnett et al. 1975), then the taste of each food added, viz. millet and maize flour in experiment 1 and millet, maize and wheat flour in experiment 2 was distinctly perceived in the mixtures. Their specific tastes by association with *poisoning became the basis of avoidance.*

Thus, no blending of tastes occurs in cereal mixtures, and the rats are not confounded. Zinc phosphide is, however, used in much higher concentrations in the field (c. 50-500 mg/10 g food), which may result in greater development of bait-shyness. One poisoning in mixtures then would make several foods ineffective restricting the choice in bait-bases needed for second or more treatment with different poisons. When long-term control operations are planned, use of mixtures as base for poisoning with zinc phosphide should be avoided. However, mixtures can be used if a single treatment is desired, or when residual supplies are to be used while other kinds of baits are abundantly available.

SUMMARY

Treatments of equivalent wt./wt. mixtures of foods-millet and maize flours, or millet, maize and wheat flours;-with zinc phosphide (4 mg/10 g food) not only make the rats ***Rattus rattus*** *L. averse to eating the original baits, but also their components.*

Practical implications of such association of 'bait-shyness' to components of the original baits, are discussed.

Table 17. Mean body-weight, with standard errors of mean (SE), of rat colonies in expts. 1 and 2.

TABLE - 17

Description of colony	No. of Rats		Body wt. ($g \pm$ S.E.)		Death
	Male	Female	Mean	Range	
Experimental	1	5	112.50 ± 6.285	90-130	130 g♀
Control	1	4	110.00 ± 6.32	91-132	..
Experimental	1	3	109.25 ± 5.52	90-122	..
Control	1	5	115.60 ± 3.04	109-130	..

Table 18. Consumption of foods (g/day $\pm$ SE) offered in expt. 1 with standard errors of mean.

TABLE - 18

Length of test (days)	Food 1	Consumption	Food 2 (Wheat flour)	% consumption
5	Millet + Maize flour	65.60 ± 5.12	16.80 ± 2.13	79.61 ; 20.39
7	Millet + maize flour + poison	8.88 ± 5.42	31.71 ± 2.75	21.72 ; 78.27
3	Millet flour	9.33 ± 0.76	33.33 ± 2.71	21.84 ; 78.16
3	Maize flour	7.66 ± 0.405	28.33 ± 0.91	21.29 ; 78.71
3	Millet + Maize flour	7.00 ± 1.14	33.00 ± 2.62	17.50 ; 82.50
Control				
12	Millet + maize flour	52.50 ± 2.752	9.33 ± 1.32	84.91 ; 15.09
3	Millet flour	53.33 ± 0.76	9.34 ± 0.76	85.14 ; 14.86
3	Maize flour	32.33 ± 1.45	10.66 ± 1.76	75.20 ; 24.80
3	Millet + maize flour	$51.66 + 1.76$	$7.00 + 0.57$	88.15 ; 11.85

Table 19. Intake of foods (g/day $\pm$ SE) by rats in experiment 2, with standard error of mean.

TABLE - 19

Length of test (days)	Food 1	Food consumption	Food 2 (Gram flour)	% consumption
5	Millet + maize + wheat flour	38.41 ± 2.10	11.23 ± 1.51	77. 4 ; 22.60
7	Millet + maize + wheat flour + poison	8.10 ± 4.15	18.30 ± 1.26	30.70 ; 69.30
3	Millet flour	5.00 ± 1.01	21.00 ± 1.32	18.21 ; 81.82
3	Maize flour	4.52 ± 1.56	23.55 ± 1.51	16.10 ; 83.90
3	Wheat flour	7.55 ± 0.15	24.00 ± 1.10	23. 8 ; 76.20
3	Millet + maize + wheat flour	4.00 ± 1.11	21.53 ± 1.00	16 ; 84
Control				
12	Millet + maize + wheat flour	57.66 ± 2.25	9.51 ± 0.88	85. 8 ; 14.2
3	Millet flour	53.00 ± 3.00	6.51 ± 1.55	89. 1 ; 10.9
3	Maize flour	51.17 ± 1.22	11.13 ± 1.33	82. 3 ; 17.7
3	Wheat flour	52.51 ± 2.54	10.52 ± 0.15	83. 3 ; 16.7
3	Millet + maize + wheat flour	54.00 ± 0.20	8.00 ± 1.31	87. 1 ; 12.9

Figure 29 : Daily consumption of test foods by experimental and control rats of expt.1. The choice for mixture and its components was reversed after poisoning.

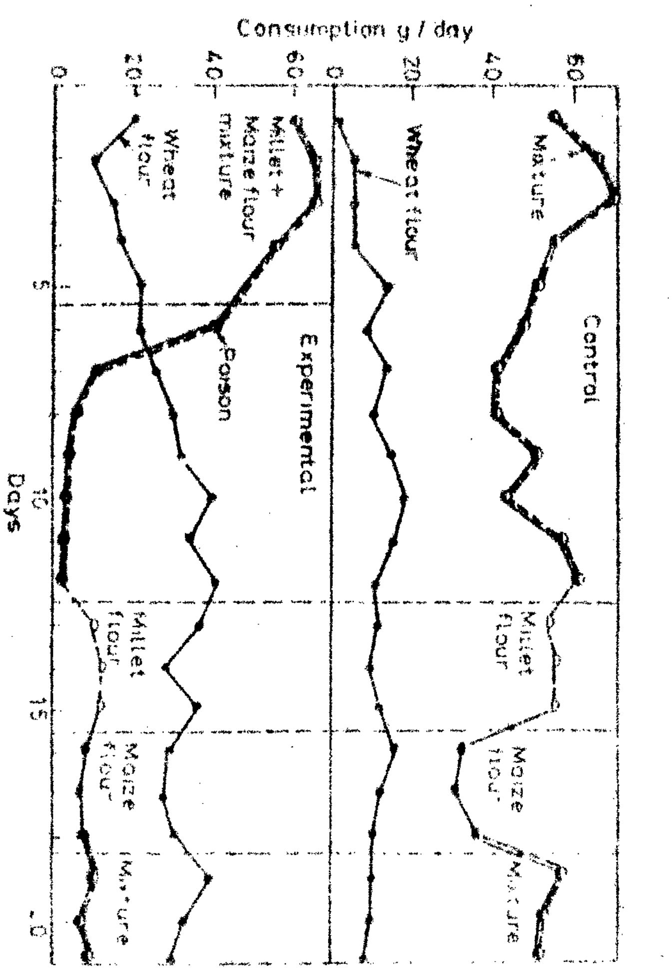

Consumption g / day
Control
Mixture
Wheat flour
Millet flour
Maize flour
Experimental
Millet + Maize flour mixture
Wheat flour
Poison
Millet flour
Maize flour
Days

Fig. 29

MITIGATING POISON & BAIT-SHYNESS DEVELOPED BY WILD RATS (RATTUS RATTUS L.):EFFECT OF POISONING AT SHORT INTERVALS

INTRODUCTION:

Poison-shyness, or aversion developed for poisonous mixtures, and 'bait-shyness', or refusal to eat foods used earlier for treatment, are the two components of a behaviour that prevents rats, as also several other mammals, from eating toxic foods (Barnett, 1975). The behaviour has survival value (Barnett & Prakash, 1975) and also much practical importance (Chitty, 1954).

Thus in practice, it becomes essential to change poisons and baits after every treatment (Barnett & Prakash, 1975). For each treatment, however, the rats have first to be attracted to the baits (pre-baiting), which is then mixed with poison (poison-baiting). With the choice of poisons and baits becoming wider, the eradication programmes apparently become tedious, time-consuming and also costly (Armour & Barnett, 1950).

It is, therefore, necessary to find alternative methods for mitigating, if not eliminating, shyness; as for example by selecting poisons and devising baits which remain effective for longer periods (Armour & Barnett, 1950).

A different procedure, often suggested, is that of using conventional poisons and baits at short intervals of a week or less. The feasibility of such schemes has not been experimentally tested.

This was examined in two separate experiments, by measuring the responses of 'black' rats, Rattus rattus L., to the bait, millet flour, treated with zinc phosphide (4 mg/10 g of food) at intervals of 3 and 6 days. Wheat flour was given as the alternative food. The results are reported here.

MATERIAL AND METHODS:

Subjects were chosen from a stock of wild-caught 'black' rats, R. rattus, maintained in our laboratory on standard diet and ad libitum water. Pregnant ♀ and juveniles ($<$60 g) were excluded, and others grouped into bisexual colonies. The colonies were housed in wire-mesh cages; 1.32 X 1.0 X 0.32 m, and provided with tins and straw for nesting.

The rats were weighed before the experiments, and mean weight of each colony was calculated. That for expt. 1 ($N = 6$) weighed 94.11 $\pm$ 7.7 g (weight range : 65-120 g), and of expt. 2 ($N = 6$) 11.2 $\pm$ 5.1 g(70-120 g). The mean weight of control colony ($N = 6$) was 95.0 + 6.8 g(65-115g).

Unextracted flour of millet (<u>Pennisetum typhoideum</u>) and wheat (<u>Triticum aestivum</u>) were used as test foods. Weighed amounts were given, and residue, including that spilled, was weighed next day. Zinc phosphide was used for treatment at the rate of 4 mg/10 g of food.

The first treatment in the preferred food, or millet flour, was given to both groups after 6 days of pre-baiting. Three more treatments followed it in expt. 1, at intervals of 3 days. In experiment 2, only two more treatments were given after gaps of 6 days. Harmless wheat flour was given as the alternative food. Untreated millet flour and wheat flour were always available during the inter-missions, i.e. for 3 consecutive days after each treatment in expt. 1 and continuously for 6 days after every treatment in expt. 2. Intakes were recoreded daily for 23 days (expt. 1) and 27 days (expt. 2) that the two experiments lasted. Control rats received the same foods simultaneously, but no poison.

Marked decline in the consumption of poisonous mixture, was taken as the evidence of 'poison-shyness'. 'Bait-shyness' was similarly indicated by the avoidance of millet flour during the intervening periods. Student's 't' test (Bailey, 1959) and Mann-Whitney U Test (Gibbons, 1971) were used for statistical analysis.

RESULTS

Results from only one colony, as examples of typical results, are given in Table 20 and illustrated in Fig.30.

Poisoning decimated the rat colonies in both experiments. Of the original 6 rats, only 3 survived in expt. 1 and 4 in expt. 2. In the former, deaths of a female (90 g), male (91 g) and another female (100 g), followed, respectively, the first, the second and the fourth or last treatment. However, both the rats of expt. 2, females (90 & 120 g), died after the third, i.e. the last treatment. The experiments were however, continued with the survivors.

Choice before Treatment — Millet or millet flour is readily preferred by the 'black' rats, R. rattus, to other cereal (Khan, 1974). Thus millet flour was favoured to wheat flour in expt. 1 ($P > 0.001$), expt. 2 ($P > 0.001$) and in controls (mean consumption/day—28.0 $\pm$ 3.6 g millet flour : 48 $\pm$ 1.49 g wheat flour; $P > 0.001$). Variable amounts of the two foods were, however, eaten on most days of prebaiting (Fig.30).

Consumption of Poisoned Food — After six days of consistent preference shown for millet flour, its *poisonous mixture, on first encounter, was also eaten in greater amounts than wheat flour. It was, however, not clearly preferred to the harmless alternative, either in expt. 1 ($P > 0.1$) or expt. 2 ($P > 0.1$). On the same day in controls, as also on subsequent occasions, millet flour was clearly selected in preference to wheat flour (Fig.30, $P < 0.05$).*

Next time, after variable intervals, the response to toxic food was similar in both experiments. It was exactly the obverse of that observed on the first occasion (Fig.30). However, wheat flour was also not clearly preferred to it (expt. 1, $P > 0.1$; expt. 2, $P > 0.1$).

When offered agin, for the third and fourth time, the mixture was eaten in still smaller amounts. However, no clear choice for harmless wheat flour was shown on either occasion ($P > 0.1$).

Effect of Poisonings on Preference:

Experiment 1 : Consumption of millet flour was reduced after the first treatment, and that of wheat flour increased simultaneously (Fig.30). The two foods were eaten in equal amounts one day after it. On the remaining 2 days, however, more of millet than wheat flour was again concumed (Fig.30). It was, however, not clearly preferred ($P > 0.1$). Thus on all the 3 days, millet flour was eaten in lesser amounts than on any of the 6 days before treatment ($P < 0.05$).

The second treatment produced the same effect of equivocal choice followed by a slight increase in the consumption of millet flour (Fig.30). The difference in relative intakes was, however, smaller than that observed after the first poisoning.

The choice was reversed after the third treatment, when wheat flour was consistently eaten in large amounts than millet flour on all the 3 days of intermission. Following the fourth treatment, it was also preferred to millet flour ($P < 0.01$). Thus the choice on the last day of experiment, was exactly the opposite of that observed at start (Fig.30). That indicated the aversion developed for millet flour, or 'bait-shyness'.

On all the 12 days simultaneously, millet flour was consistently selected by controls in preference to wheat flour (Fig.30, $P < 0.01$).

Experiment 2 : The first treatment produced the same response as that observed in expt. 1, on the following day, millet and wheat flours were eaten in equivalent amounts. But more of the former was consumed on the remaining five days (Fig.30). It was, however, not clearly preferred to the alternative food ($P > 0.1$). Thus on all days of intermission, millet flour was accepted in lesser amount in comparison to its consumption before treatment ($P < 0.05$).

Only after the second poisoning, the rats of expt. 2, unlike the rats of expt. 1, changed over to eating more wheat than millet flour. Following the third or last treatment, it was even more favoured ($P < 0.01$). Thus prolonging the gap between treatments, did not lessen the aversion for the bait.

In controls, however, millet flour was continuously eaten in preference to wheat flour (Fig.30, $P < 0.05$).

DISCUSSION

During the otherwise continuous baiting with the two cereals, the preferred alternative was poisoned (1) intermittently (2) at intervals of 3 days in expt. 1 and 6 days in expt. 2. None of the two variables, however, could mitigate 'shyness', much less eliminate that, which developed for both the poison and bait (Fig.30, Table 20). It increased after every treatment, and the responses were obviously similar in both experiments (Fig.30).

Thus after initial acceptance in both groups, the poisonous mixture was eaten in smaller amounts on subsequent occasions (Table 20, Fig.30). The response is very typical of that described for this species in alternative situations of continuous treatment (Barnett et al, 1975). It only shows that 'poison-shyness' to zinc phosphide *is not only developed rapidly, but is also retained for short periods, of upto a week (Table 20).*

That the poisonous mixture is accepted on the first occasion (Fig.30), is very likely. Zinc phosphide is a secondary poison (Armour & Barnett, 1950) and its slow effects can hardly be felt during the time, one night, that it is eaten on first encounter. But that it has some specific taste, is quite obvious. Evidently on that basis (Barnett _*et al*_*., 1975) it must have been avoided when offered again (Fig.30). Involvement of 'learning' in the development of 'poison-shyness' is thus clearly indicated.*

There are two immediate effects of a poisoning on the preferences of the rats. First, that it diverts the choice. Thus the rats being unable to decide about preference, ended up by eating millet and wheat flours in equal amounts (Fig.30, Table 20). This may have been the result of increased sampling (Rozin & Kalat, 1971). It also happens, however, when the rats are made to choose between two equally palatable, but harmless foods (Khan, 1974).

Secondly, that to begin with the poison produces only a mild aversion for the bait. Thus millet flour was again accepted on most days after the first treatment (Fig.30), though was not clearly preferred to alternative wheat flour (Table 20). The treatments that followed obviously; added up to it, and the aversion increased; as observed after the third treatment in expt. 1 and second treatment in expt. 2 (Fig.30). It is but clear evidence of 'learning' to avoid baits. Hence, baits like millet flour can hardly prove effective when used again.

Alternatively, if the rats learn to accept foods that are sampled without ill-effects, or 'learned safety' (Kalat & Rozin, 1973), the responses of our rats would have been different. Owing to the slow, but uniform, action of poison, the poisoned food may have been sampled for equal durations; and nearly eaten in the same amounts on all occasion that it was offered. Similarly, marked readiness to eat the harmless millet flour would have been shown during the intervening periods. This specially applies to expt. 2 where it was available, without poison, for six days following every treatment.

Nothing like the above, however, is observed (Table 20, Fig.30). There is no evidence about the 'learned safety' effect, much less of its interference in 'poison-shyness' (Barnett et al., 1975). Clearly, the aversive action of poison causes 'shyness', and the sense of taste plays a prime role in the discriminations involved (Barnett et al., 1975).

Thus the behaviour of our rats is very significant, *and also conclusive. It precludes any possibility of using zinc phosphide, or similar other acute poisons, and millet flour, or conventional baits, for intermittent treatments against this pest.*

SUMMARY

Groups of wild rats receiving cereals (millet and wheat flours) were poisoned in the preferred alternative with zinc phosphide (4 mg/10 g of food), at intervals of 3 or 6 days. The schedules followed did not mitigate 'shyness' that developed for both the poison, 'poison-shyness', and the bait, 'bait-shyness'. The responses 'shown are, however, very relevant for analysing the processes which enable the rats to acquire shyness.

****

Table 20. Daily consumption of millet and wheat flour before treatment and during the intervening periods of 3 days (Expt. 1) and 6 days (Expt.II) when no poison was given. Intakes recorded on treatment days are also given.

TABLE - 20

VALUES ARE MEAN ± SE AND EXPRESSED AS g/day

Foods offered	Experiment I		Experiment II	
	Consumption	% Total (N=3) consumption	Consumption	% Total (N=6) consumption
Millet Flour	58.6 ± 2.3	89.3	41.0 ± 1.9	80.4
Wheat Flour	7.0 ± 1.4	10.7	10.0 ± 2.1	19.6
Millet Flour + Pioson	32.0 ± 0	61.5	30.0 ± 0	66.7
Wheat Flour	20.0 ± 0	38.5	15.0 ± 0	33.3
Millet Flour	31.6 ± 4.4	59.3	25.3 ± 1.1	57.4
Wheat Flour	21.6 ± 3.3	40.7	18.8 ± 1.5	42.6
Millet Flour+Poison	18.0 ± 0	37.5	15.0 ± 0	33.3
Wheat Flour	30.0 ± 0	62.5	30.0 ± 0	66.7
Millet Flour	24.3 ± 2.3	53.3	13.1 ± 1.9	33.2
Wheat Flour	21.3 ± 0.82	46.7	26.3 ± 1.5	66.8
Millet Flour + Pioson	10.0 ± 0	29.4	5.0 ± 0	14.3

Contd. on page next

Table 20 (Contd.)

Foods offered	Experiment I		Experiment II	
	Consumption	% Total (N=3) consumption	Consumption	% Total (N=6) Consumption
Wheat Flour	24.0 ± 0	70.6	30.0 ± 0	85.7
Millet Flour	8.3 ± 1.0	23.3	9.1 ± 1.2	27.0
Wheat Flour	27.3 ± 2.7	76.7	24.6 ± 2.7	73.0
Millet Flour + Poison	4.0 ± 0	8.7		
Wheat Flour	42.0 ± 0	91.3		
Millet Flour	4.0 ± 0.58	10.5		
Wheat Flour	$34.0 + 1.0$	89.5		

Mean daily consumption in controls ($N = 27$) : 46.7 g millet flour, 11.1 g wheat flour.

Figure 30 : *Daily consumption of millet (O) and wheat flour (X) in control, and experimental colonies that were poisoned in millet flour (●) at intervals of 3 days (expt.1) and 6 days (expt.2). Unlike the consistent preference for millet flour in controls, the experimental rats gradually changed over to eating wheat flour; avoiding both the poisonous mixture (●) and the bait (O)*

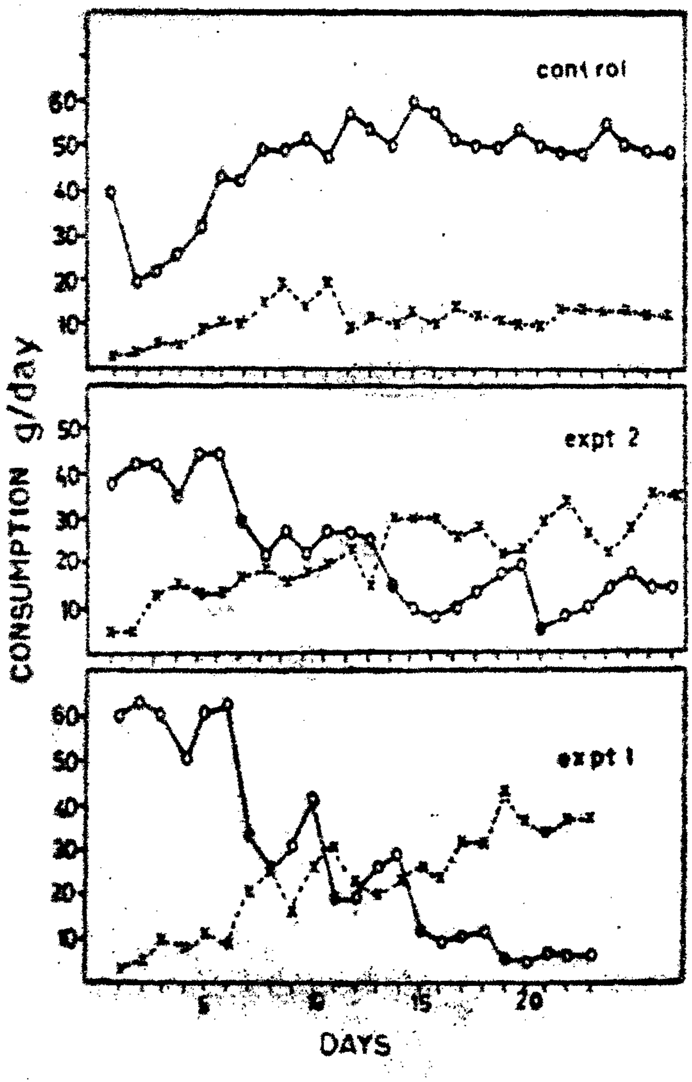

control
expt 2
expt 1
CONSUMPTION g/day
DAYS
60
50
40
30
20
10
5
10
15
20

Fig. 30

MITIGATING "POISON – & BAIT-SHYNESS" DEVELOPED BY WILD RATS (RATTUS RATTUS L.) : II RESPONSES TO NON-OILY BAITS AFTER POISONING IN OILY BAIT-MIXTURES

INTRODUCTION

Ever since that it has been clearly described, there have been many studies of the behaviour of "bait-shyness" (reviewed by Barnett, 1975). These have aimed at either quantitative evaluation of the behaviour in one or the other rodent species, or at most in finding out the sensory cues involved in it (Prakash & Jain, 1971; Prakash et. al., 1975; Barnett et. al., 1975; Cowan, 1978). Experimental analogs of it, have, however, been used in a wide variety of conditioning studies; that show the involvement of learning, or neural control exercised over the behaviour (Garcia, 1970).

There is, however, one aspect of the study of shyness that has been denied attention, inspite of what it seems to have consistently deserved all along (Armour & Barnett, 1950). This is about the methods that can be devised either to avoid or eliminate shyness. Thus, the behaviour is very disadvantageous *from an applied view-point, (1) frequent changes in baits and poisons present many difficulties in the field, (2) and because survivors among rats from previous poisoning compaigns are more so difficult to poison and eliminate (Garcia, 1970; Barnett,& Prakash, 1975).*

As at present thus, there is no method of avoiding or *eliminating shyness; though some advantage can be had by a change in textural state, so that the original food (cereal or whole pulses) can be used again as bait. Similarly, it is reduced to some extent by addition of groundnut oil to original base. It is, however, found on the other hand, that shyness is not eliminated by poisoning rats in mixtures of foods, or* by treatments *at intervals of 3 or 6 days.*

However, some baiting materials for the purpose have not yet been tested in the laboratory; as for example a "bait-base" containing two or *three cereals in ground from to which groundnut oil is also added. Thus, the presence of oil may interfere with "tastes"; preventing the rats from discriminating any components against taste* and *asso-ciating the same to poisoning. In that case, the components can be used again for poisoning the rats.*

Accordingly, the responses of rats, Rattus rattus *L., to components of original oily base was tested after poisoning in it with zinc phosphide (4 mg/10 g food). The* results are discussed here.

MATERIAL AND METHODS

The Subjects: The subjects were wild-caught stock. They were sexed, weighed and grouped into colonies. A laboratory rat diet was given before the experiments started. Water was offered *ad lib*.

Description of colonies is given in Table 1.

Test Foods: Unextracted flours of millet (*Pennisetum typhoides* Burm), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and Bengal gram (*Cicer arienatum* L.) were included among test foods.

Cereals were used in equivalent wt./wt. mixtures, viz. of (1) millet and maize flours, (2) or millet, maize and wheat flours. These were prepared by adding 50 g of each to a container, and mixing the content thoroughly. Gram flour was not used in any mixture.

Oil of groundnut (*Arachis hypogea* L.) was added to cereal mixture in concentration of 5% (w/w).

Experimental Procedure: In expt. 1, millet and maize flour were compared seperately to wheat flour for 2 days each. After this, millet flour and maize flour mixture, and the same with groundnut oil were compared to alternative wheat flour for an equivalent duration. On the following 7 days, the rats were poisoned in oily bait-mixture with zinc phosphide at the rate of 4 mg/10 g food. After poisoning, the choice of rats for foods, in same order and combinations as given before, was observed again.

The same procedure was followed in Expt.2. But the choice of rats was first found seperately between wheat, millet, maize flours and gram flour; then between millet + maize + wheat flour and gram flour, and lastly in comparison to same food for millet + maize + wheat flours + oil. The rats were poisond in oily bait-mixture, of three cereal foods. After this, choice for foods as given before, was determined again.

Controls of both experiments were given the same foods simultaneously; but they were not given any poison.

Consumption was measured daily for 23 days in Expt.1 and 27 days in Expt.2. Replicates, two to each Expt., were run simultaneously.

Analysis of Results: Methods described by Bailey(1959) and Lehner (1979) have been followed for statistical analysis of results.

RESULTS

The results are summarised in Tables 21 & 22. Results *of Expt.1 are also illustrated in Fig.31.*

Selection of Test Foods: "Roof" rats are found to show orderly choice between foods (Khan, 1974). Among cereals thus, millet, maize and wheat flours are selected in the order named; while in cross-tests between different kinds of foods, cereals are more preferred than pulses (Khan, 1974).

The same kind of preferences were also demonstrated by rats of Expt.1 & 2. In Expt.1 thus, millet and maize flour mixture, as also each food seperately, was preferred to wheat flour ("t" test, $P < 0.05$; Table 21, Fig.31). Similarly, rats of Expt.2 preferred each cereal, and then the mixture of all the three foods, to gram flour ("t" test, $P < 0.05$; Table 22).

Groundnut oil is found to have increased the preference for mixtures only slightly (Tables 21 & 22). Had the length of tests been increased, the effect of its addition might have been greater. Thus, the physiological effects of a favourable kind, which the oil undoubtedly has, are slow to appear (Khan, 1974; Barnett, 1975).

Effect of Poisoning: Zinc phosphide was added to preferred foods, or oily bait-bases. Therefore, only a small difference in its consumption was noticed on the first day of poisoning (Fig.31). However, avoidance became more obvious on the following days (Mann. Whitney

"U" test, $P < 0.05$); as the rats increased the intake of harmless alternatives, wheat or gram flour (Fig.31).

Eventually, the choice was reversed by poisoning in both experiments ("t" test, $P < 0.05$; Tables 21 & 22). The rats had switched-over to eating the alternatives, while toxic oily bait-bases were declined (Tables 21 & 22; Fig.31).

The oily bait-mixtures were, however, greatly preferred earlier by the rats to the same plain alternatives; as they still were in the controls (Tables, 21 % 22; Fig.31). This was clear evidence of the development of avoidance, or refusal to eat poisoned foods (poison-shyness).

Responses to Foods After Poisoning: In Expt.1, the oily bait-mixture (millet + maize flour + oil) in which the rats had ingested poison, was consistently rejected by them afterwards, even in harmless form (Table 21; Fig.31). However, the same mixture without oil, and each of it's two components - millet flour and maize flour; were eaten preferentially by rats in comparison to wheat flour ("t" tests, $P < 0.05$; Table 21, Fig.31). Except for the original oily bait, the same choices were shown in corresponding controls (Table 21; Fig.31).

Similarly, the rats of Expt.2 rejected the original *mixture (millet + maize + wheat flour + oil); gram flour was preferred to it ("t" test, $P < 0.05$; Table 22). However, non-oily bait-mixture:millet + maize + wheat flour; and each component of it, was seperatly preferred to gram flour again, as before poisoning ("t" test, $P < 0.05$; Table 22). The same choices were also shown by the controls (Table 22).*

Thus, the rats of both Expts. became averse to eating the original baits (oily) in which they had been poisoned (bait-shyness). However, shyness was not broadened to non-oily baits, or to it's components (Tables 21 & 22; Fig.31).

DISCUSSION

Zinc phosphide is a slow-acting, secondary poison (Barnett et. al., 1975). However, the behavioural effects of sub-lethal doses of it, studied by observations on different species of wild rats, are found to correspond closely (Barnett et. al., 1975; Htun & Brooks, 1979). Unlike other poisons, used in experimental analogs devised for study of this behaviour (Garcia et.al. 1972 ; Garcia et.al. 1974), which have presuambly a direct action; zinc phosphide for rather acting conversely, has a different effect. It fails to produce "total avoidance response" from the rats. Thus, the mixtures of poison with attractive foods, as oily bait-mixtures, are avoided only gradually; but never completely ignored (Fig.31).

Presuambly, a neural mechanism is involved, to control the behaviour that develops after an encounter with poisoned foods. It specifically bridges the gap between the sensory inputs and response, of avoidance, that follows. This is, however, not exactly known; though of sensory cues, "taste" is obviously important. It is associated with all processes related to the eating of foods (Garcia, 1970; Garcia et.al., 1974); while dissociation of odour from taste in bait-shyness, has been variously confirmed (Barnett, et.al., 1975).

In this regards, the relevance of an opposite action of "learned safety" for wild rats has, however, been emphasized too (Rozin & Kalat, 1971; Kalat & Rozin, 1973; Barnett et.al., 1975). It may also be important; but aversive effects of poison seem to have a greater role in inducing shyness than perhaps the action of "learned safety". Thus, the alternative method of poisoning rats at short intervals has almost a similar effect as continuous treatment with zinc phosphide. Apparently, the "tastes" linger on; so that ever increasing effects of poison, prevent eating of original baits or it's components on subsequent encounters, with or without intervals in between.

Accordingly, it would appear that poisonous mixtures were discriminated against their taste; and avoidance followed the development of "poison-shyness" in rats to zinc phosphide (Table 21; Fig.31). Thus, the harmless form was eaten as before, by rats of controls. However, treatment also caused aversion to eating of original baits, or "bait-shyness". Evidently, the characteristic "taste" of such complex baits-cereal mixture and oil; was also distinctly perceived. The specific tastes of bases became, by association with poisoning, the basis of avoidance.

It is seen, however, that "bait-shy" rats accepted the non-oily base and it's components, again (Table 21; Fig.31). Evidently, shyness is not "broadened" to non-oily baits or it's components after poisoning in oily bait-mixtures. When cereal mixtures are used for poisoning without oil, however, the original bait and it's components are rejected by the "bait-shy" rats (Cahpter IX). Obviously the presence of groundnut oil is responsible for the difference observed.

This is possible too, as groundnut oil has a "masking" effect on the taste of cereal mixed with it (Chapter VIII). Probably, something like this may have prevented the rats from successfully discriminating the cereal added to the mixtures; for otherwise, the taste of each food in it is distinctly perceived (Chapter IX).

That alterations of taste as with texture, prevent the rats from developing shyness has thus also been demonstrated (Chapter VI & VII).

It is, therefore, concluded that shyness can be avoided *by poisoning rats in baits prepared by mixing two or more cereal foods, to which groundnut oil is also added in small concentrations. Non-oily forms of such a bait can then be used again for treatment with different poisons.*

Results from the field where zinc phosphide is used in higher concentrations (c. 50-500 mg/10 g food) are, however, awaited to prove the utility of this method of eliminating shyness.

SUMMARY

The rats, Rattus rattus L., poisoned with zinc phosphide (4 mg/10 g food) in mixtures of cereals-millet and maize flour or wheat flour, to which oil of groundnut (Arachis hypogea L.) was also added (5% W/W); avoided the oily baits (bait-shyness), but again selected the corresponding mixtures and it's components. Shyness was not broadened to non-oily foods presuamably because of failure of rats to discriminate between the same foods in the original oily base.

Thus, the rats can be poisoned repeatedly in the same cereals, first in a mixture of foods with groundnut oil and then in the mixture, or each food seperately, without oil. This requires confirmation, however, for high concentrations of zinc phosphide (C.50-500 mg/10 g food) used in the field.

Table 21 : Consumption of cereal foods, cereal mixture, cereal mixture containing oil and toxic foods in the oily base by rats of expt.1. The oily cereal mixture was rejected after poisoning, but non-oily foods were preferred again.

TABLE - 21

EXPT. NO.	Length of Test (Days)	MEAN DAILY CONSUMPTION OF FOODS, g/DAY±S.E.				% Consumption of foods
		Food 1	Consumption	Food 2	Consumption	
1						
Expt. Colony						
	2	Maize Flour	32. 5 ± 0.11	Wheat Flour	15.00 ± 3.01	68 ; 32
	2	Millet Flour	47. 5 ± 2.41	Wheat Flour	14.00 ± 1.01	77 ; 23
	2	Millet+Maize Flour	46. 0 ± 1.00	Wheat Flour	13. 5 ± 1.51	77 ; 23
	2	Millet+Maize Flour+Oil	47. 5 ± 2.51	Wheat Flour	11. 5 ± 1.51	81 ; 19
	7	Millet+Maize Flour+Oil+ Poison	9. 4 ± 5.71	Wheat Flour	14. 0 ± 1.00	28 ; 72
	2	Millet+Maize Flour+Oil	3. 0 ± 1.42	Wheat Flour	19. 0 ± 1.00	9 ; 91
	2	Maize Flour	25. 0 ± 1.00	Wheat Flour	19. 0 ± 1.00	56 ; 44
	2	Millet Flour	37. 5 ± 2.41	Wheat Flour	15.00 ± 0.0	71 ; 29
	2	Maize Flour + Millet Flour	29.00 ± 1.00	Wheat Flour	11.00 ± 1.00	72 ; 28

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Table 21 Contd.

Expt. No.	Length of test (Days)	MEAN DAILY CONSUMPTION OF FOODS, g/DAY ± S.E.				% Consumption of foods
		Food 1	Consumption	Food 2	Consumption	
Control						
	2	Maize Flour	20.00 ± 2.00	Wheat Fl.	2.5 ± 0.55	88 ; 12
	2	Millet Flour	29.00 ± 1.00	Wheat Fl.	4.5 ± 0.51	86 ; 14
	2	Maize + Millet Flour	29.00 ± 1.00	Wheat Fl.	8.0 ± 2.00	78 ; 22
	11	Maize + Millet Flour + Oil	31.2 ± 0.54	Wheat Fl.	8.7 ± 0.45	78 ; 22
	2	Maize Flour	25.0 ± 1.00	Wheat Flour	10.0 ± 0.00	72 ; 28
	2	Millet Flour	29.0 ± 1.00	Wheat Fl.	8.0 ± 0.00	78 ; 22
	2	Maize + Millet Flour	31.0 ± 1.00	Wheat Fl.	9.0 ± 1.00	78 ; 22

Table 22 : The rats of expt.2 selected cereals and cereal mixtures in preference to gram flour. The cereal mixture containing oil, was rejected following treatment with Zinc phosphide. The non-oily mixture and each of its three components were preferred again. The same preference for non oily foods was also shown by controls.

TABLE - 22

Expt. No.	Length of test (Days)	MEAN DAILY CONSUMPTION OF FOODS, g/DAY ± S.E.				% Consumption of foods
		Food 1	Consumption	Food 2	Consumption	
2						
Expt. Colony						
	2	Maize Flour	31.0 ± 3.00	Gram Fl.	4.5 ± 0.51	88 ; 12
	2	Wheat Flour	33.5 ± 1.51	Gram Fl.	3.0 ± 1.00	91 ; 9
	2	Millet Flour	31.5 ± 0.51	Gram Fl.	3. 5 ± 0.51	90 ; 10
	2	Maize + Wheat + Millet Fl.	31.0 ± 1.00	Gram Fl.	6.0 ±00	84 ; 16
	2	Maize + Wheat + Millet Fl.+ Oil	34.0 ± 1.00	Gram Fl.	8.5 ± 0.54	80 ; 20
	7	Maize + Wheat + Millet + Oil + Poison	6.0 ± 3.11	Gram Fl.	14.1 ± 0.88	30 ; 70
	2	Wheat Fl.+Millet + Maize Fl.+ Oil	2.0 ± 00	Gram Fl.	14.5 ± 0.55	12 ; 88
	2	Maize + Wheat + Millet Flour	24.5 ± 0.53	Gram Fl.	7.0 ± 1.00	77 ; 23
	2	Maize Flour	29.0 ± 1.00	Gram Fl.	5.5 ± 1.51	84 ; 16
	2	Wheat Flour	29.0 ± 1.00	Gram Fl.	7.5 ± 0.51	76 ; 24
	2	Millet Flour	29.0 ± 1.00	Gram Fl.	6.5 ± 0.52	82 ; 18

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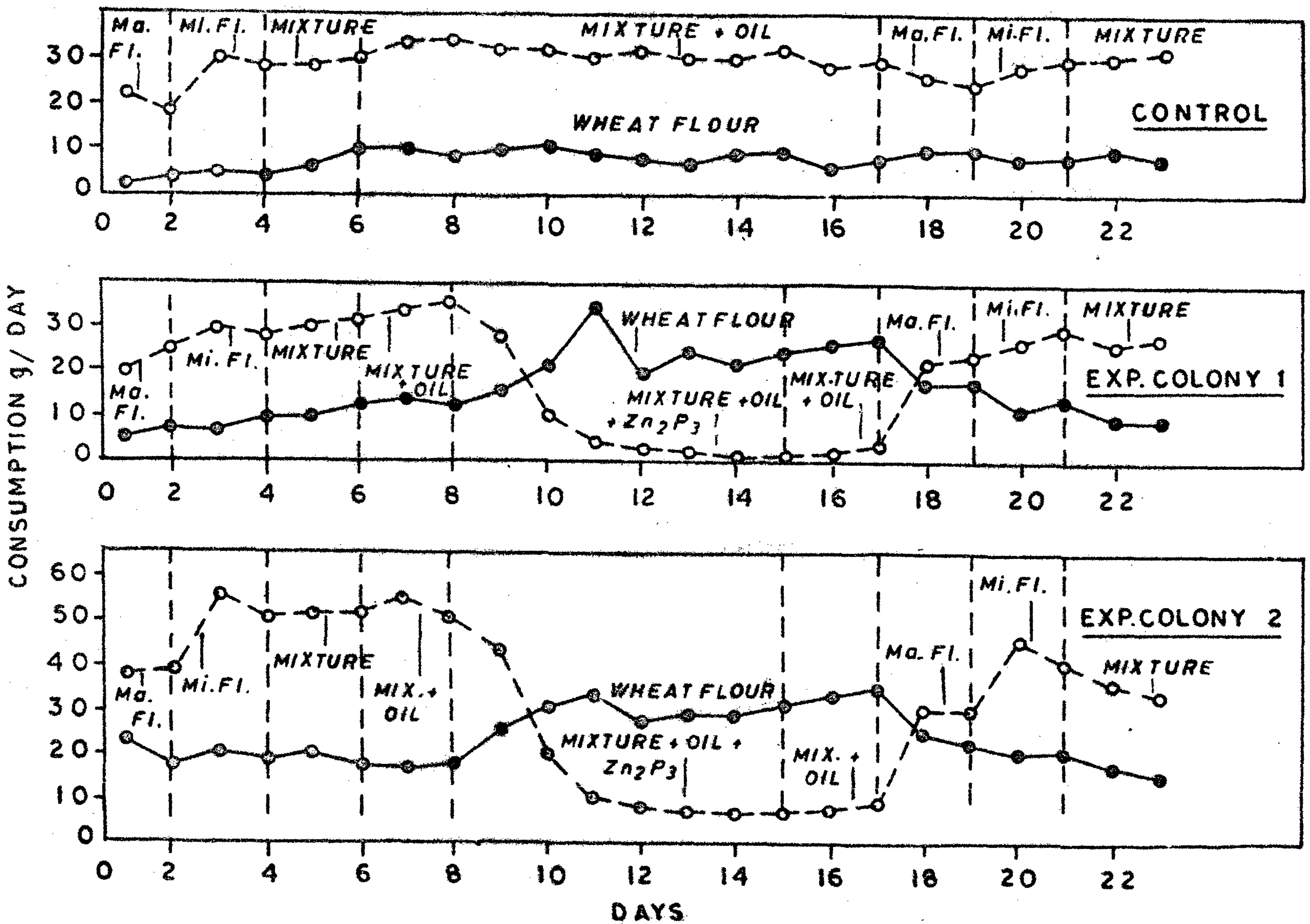
Table 22 Contd.

Expt. No.	Length of Test (Days)	MEAN DAILY CONSUMPTION OF FOODS, g/DAY ± S.E.				% Consumption of foods
		Food 1	Consumption	Food 2	Consumption	
Control						
	2	Maize Flour	32.5 ± 7.51	Gram Fl.	4.00 ± 1.00	89 ; 11
	2	Wheat Flour	43.5 ± 1.41	Gram Fl.	7.0 ± 00	86 ; 14
	2	Millet Flour	50.00± 5.00	Gram Fl.	8.0 ± 1.41	86 ; 14
	2	Wheat+Maize+Millet Flour	43.5 ± 0.51	Gram Fl.	7.5 ± 0.55	85 ; 15
	11	Wheat+Maize+Millet Flour + Oil	40.3 ± 1.33	Gram Fl.	8.9 ± 0.44	84 ; 16
	2	Wheat+Maize+Millet Flour	41.5 ± 1.00	Gram Fl.	7.0 ± 00	86 ; 14
	2	Maize Flour	37.5 ± 2.51	Gram Fl.	9.0 ± 1.00	81 ; 19
	2	Wheat Flour	32.5 ± 2.52	Gram Fl.	9.0 ± 1.00	78 ; 22
	2	Millet Flour	39.00± 1.00	Gram Fl.	6.0 ± 1.00	86 ; 14

Figure 31 : *The figure shows the amount of test foods eaten in experimental and control colonies of the expt.1. Poisoning in oily cereal mixture does not alter the choice for the mixture and its components offered without oil. The presence of oil prevents the development of bait shyness.*



CONSUMPTION g/ DAY
DAYS
CONTROL
EXP. COLONY 1
EXP.COLONY 2
Ma. Fl.
Mi. Fl.
MIXTURE
MIXTURE + OIL
WHEAT FLOUR
MIXTURE + OIL + Zn_2P_3
MIX. + OIL
0 2 4 6 8 10 12 14 16 18 20 22
0 10 20 30 40 50 60

Fig. 31

REFERENCES

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Armour, C.J. & Barnett, S.A. 1950 : The action of dicoumarol on laboratory and wild rats, and its effect on feeding behviour. J.Hyg., Cambridge, 48 : 158-170.

Aykroyd, W.R. 1963 : The nutritive value of Indian foods and the planning of satisfactory diets. Special Report Series, No.43, 6th rev.ed., New Delhi : ICMR.

Aziz, S.A. 1965 : A survey of synanthropic rodents and their fleas in district Dhanbad, Bihar, India. Bull.Indian Soc.Malaria Commun.Dis., 2(4) : 318-326.

Bailey, N.T.J. 1959 : Statistical methods in biology. (English University Press, London).

Barbehenn, K.R. 1962 : In 'Pacific Island Rat Ecology'. (T.I. Storer, Ed.) Honolulu : Bishop Museum pp. 223-232.

Barnett, S.A. 1956 : Behaviour components in the feeding of wild and laboratory rats. Behaviour, 9 : 24-43.

Barnett, S.A. 1958 : Experiments on "neophobia" in wild and laboratory rats. British J. Psychol., 49 : 195-201.

Barnett, S.A. 1969 : The feeding of rodents. Proc.Indian Rodent Symp., Calcutta, pp. 113-123.

Barnett, S.A. 1975 : The Rat : A study in behaviour. (Chicago University Press, Chicago).

Barnett, S.A.; Cowan, P.E.; Radford, G.G. and Prakash, I. 1975 : Peripheral anosmia and discrimination of poisoned food by Rattus rattus L. Behav. Biol., 13 : 183-190.

Barnett, S.A.; Dickson, R.G.; Marples, T.G. and Radha, E. 1978 : Sequence of feeding, sampling and exploration by wild and laboratory rats. Behavioural Processes, 3 : 29-43.

Barnett, S.A. & Prakash, I. 1975 : Rodents of economic importance in India. (Arnold-Heinemann Press, New Delhi).

Barnett, S.A. & Spencer, M.M. 1951 : Feeding, social behaviour and interspecific competition in wild rats. Behaviour, 3 : 229-242.

Barnett, S.A. & Spencer, M.M. 1953 : Experiments on the food preferences of wild rats (Rattus norvegicus, Berkenhout). J. Hyg., Cambridge, 51 : 16-34.

Beck, R.C. 1967 : Clearance of ingested sucrose solutions from the stomach and intestine of the rat. J. Comp. Physiol. Psychol., 64 : 243-249.

Bell, G.H., Davidson, J.N & Scarborough, H. 1965 : Text book of physiology and bio-chemistry (Livingstone, London), pp. 1140.

Bhardwaj, D. 1976 : Effect of texture on the food preferences of 'bait-shy' wild rats (Rattus rattus L.). M.Phil. Thesis, AMU, Aligarh.

• Bhardwaj, D. & Khan, J.A. 1976 : Food requirement of "black rat", Rattus rattus L. J. Bombay Nat. Hist. Soc., 71 : 605-608.

• Bhardwaj, D. & Khan, J.A. 1977 : Mitigating poison and bait-shyness developed by wild rats (Rattus rattus L.) : Effect of poisoning at short intervals. Indian J. Exp. Biol., 15 : 624-626.

• Bhardwaj, D. & Khan, J.A. 1978 : Sugar preferences of "black rats", Rattus rattus L. Zool.J.Linn.Soc. 64 : 41-50.

• Bhardwaj, D. & Khan, J.A. 1978 : Effect of texture on the food preferences of bait-shy wild rats (Rattus rattus L.). Proc. Indian Acad.Sci., B 87 : 77-80.

• Bhardwaj, D. & Khan, J.A. 1979a : Responses of roof rat, Rattus rattus L. to non oily and oily foods after poisoning in oily foods. Proc. Indian Acad.Sci., B 88 : 125-129.

• Cited Originally in texts published

• Bhardwaj, D. & Khan, J.A. 1979b : Effect of texture of food on bait-shy behaviour in wild rats (Rattus rattus L.) Appl. Anim. Ethology, 5 : 361-367.

• Bhardwaj, D. & Khan, J.A. 1980 : Responses of Rattus rattus L., to foods previously used in a mixture for poisoning with Zinc phosphide. Proc. Indian Acad. Sci., B 89 :215-219.

Bhatnagar, J.K. 1969 : The role of rodents in the epidemiology of plague in Uttar Pradesh. Ind. Rod. Sym., Calcutta, Dec. 8-11, pp. 204-215.

Bhattacharya, T.P. 1973 : On some melanistic specimens of house rat, Rattus rattus (Linnaeus) (Mammalia) : Rodentia : Muridae. J. Bombay Nat. Hist. Soc., 70(1) : 195-196.

Boice, R. & Boice, C. 1968 : Trapping Norway rats in a land fill. J. Sci. Lab. Denison Univ., 49: 1-4.

Booth, D.A., Lovett, D. & Mcsherry, G.M. 1972 : Post-ingestive modulation of the sweetness preference gradient in the rat. J. Comp. Physiol. Psychol., 78 : 485-512.

Cameron, A.T. 1947 : The taste sense and the relative sweetness of sugars and other sweet substances. Sugar Res. Found. Sci. Rep. Ser., No. 9.

Campbell, B.A. 1958 : Absolute and relative sucrose preference thresholds for hungry and satiated rats. J. Comp. Physiol. Psychol., 51 : 795-800.

Carr, W.J. 1952 : The effect of adrenalectomy upon the Nacl taste threshold in rat. J. Comp. Physiol. Psychol., 45 : 377-380.

Chakravarti, I.M. Laha, R.G. and Roy, J. 1967 : Handbook of methods in applied statistics. Vol.I (John Wiley & Sons, New York).

Chandrahas, R.K. & Krishnaswami, A.K. 1971 : Flea fauna on domestic rodents in some areas of the south Indian plague focus. Ind. J. Med. Res., 59 : 1816-1821.

Chaturvedi, G.C. & Deoras, P.J. 1972 : A note on a high incidence of fleas (Siphonaptera) infestation in Rattus rattus (Rodentia). J. Bombay Nat. Hist. Soc., 69(2) : 436-437.

Chaturvedi, G.C., Madsen, C.R. & Thakore, K.M. 1977 : Studies on Efficacy of different anticoagulant rodenticides on Rattus rattus (house rat). Proc. All India Rodent Seminar Ahmedabad, 23-26, pp.139-141.

Chitty, D. 1954 : Control of rats and mice. (Clarendon Press, Oxford).

Chitty, D. & Shorten, M. 1946 : Techniques for the study of the Norway Rat (Rattus norvegicus). J. Mammol., 27 : 63-78.

Chitty, D. & Southern, H.N.(ed.) 1954 : 'The Control of Rats and Mice'. Oxford : Clarendon Press.

Cowan, P.E. 1978 : Poison and bait-shyness in two species of gerbil, Meriones hurrianae and Tatera indica. Zeit. angew. Zoologie pp. 56-78.

Cowan, P.E. & Barnett, S.A. 1975 : The new-object and new-place reactions of Rattus rattus L. Zool. J. Linn. Soc., 56 : 219-234.

Cowan, P.E. & Prakash, I. 1977 : House rats from the Indian Arid Zone. Z. angew. Zool., 65(2) : 187-194.

Deoras, P.J. 1960 : Studies on Bombay rats : a note on the probable resistance of B. bengalensis to plague. Curr. Sci. 29 : 475.

Deoras, P.J. 1963 : Studies on Bombay rats : frequency of rat population. Curr. Sci., 32 : 163-165.

Deoras, P.J. 1965a : Rodents & rodent ectoparasites in the North Arcot district of Madras State, India. World Health Organ. Inf. Circ. rect. Contr., 7 : 35.

Deoras, P.J. 1965b : Trial of two modern rodenticides. Curr. Sci., 34(11) : 348-349.

Deoras, P.J. 1966 : Tolerance of an anticoagulant by Rattus rattus. Curr. Sci., 35(1): 415.

Deoras, P.J. 1967 : Tolerance status of some rats to anticoagulant rat poisons. Curr. Sci., 36(8) : 207-208.

Deoras, P.J. 1968 : Pilot field experiments for rat reduction in four villages near Panvel in Maharashtra. Proc. First Conven. Indian Pest Contr. Ass. (Delhi).

Deoras, P.J. 1969 : Significance of probable change of rat population in Bombay. Ind. Rod. Symp., Calcutta, Dec. 8-11. pp. 58-68.

Deoras, P.J. & Gokhale, M.S. 1958 : Some biometrical observations on the common rats of Bombay. J. Bombay Nat. Hist. Soc., 55 : 450-459.

Deoras, P.J. & Tonpi, K.V. 1956 : Studies on Bombay rats. I. Collection of fleas from Rattus rattus and Bandicota bengalensis in Bombay city. J. Univ. Bombay, 25(3) : 13-22.

Dhar, G.M., Prasad, B.G., Bhatnagar, J.K. & Mathur, Y.D. 1972 : A survey on rats, rat fleas house-flies and mosquitoes in village Rahimabad, Lucknow district. Ind. J. Med. Res., 60(8) : 1232-1241.

Dharmaraju, E. 1977 : Rodent control operations in Andhra-Pradesh. Proc. All India Rodent Seminar, Ahmedabad, Sep. 23-26, pp. 214-15.

Doty, R.E. 1945 : Rat control on Hawaiian sugar cane plantation. Hawaiian Planter's Record, 49 : 71.

Ellerman, J.R.	*1947*	:	*A key to the Rodentia inhabiting India, Ceylon and Burma, based on collection in the British Museum, J. Mammal., 28 : 249-279, 357-387.*
Ellerman, J.R.	*1963*	:	*The fauna of India, Mammalia, Vol.3 (Rodentia), parts 1 and 2. Govt. of India, Delhi, pp. 849.*
Elton, C. & Ranson, R.M.	*1954*	:	*Containers for baiting. In Chitty, D. & Southern, H.N.,(ed.); 'The Control of Rats and Mice', Vol.2*
Evans, C.S., Smart, J.L. & Stoddart, R.C.	*1968*	:	*Handling methods for wild house mice and wild rats. Lab. Animals, 2 : 29-34.*
Everyman's Encyclopaedia	*1959*		
Ewer, R.F.	*1971*	:	*The biology and behaviour of a free-living population of black rats. Anim. Behav. Monogr., 4 : 127-174.*
Galef, B.G.,Jr. & Clark, M.M.	*1972*	:	*Mother's milk and adult presence : Two factors determining initial dietary selection by weanling rats. J. Comp. Physiol. Psychol., 78 : 220-225.*
Garcia, J.	*1970*	:	*Conditioning and learning factors in the regulation of food intake. Proc. American Association for the Advancement of Science, 137th Meeting, pp.1-8.*
Garcia, J. Hankins, W.G. & Rusiniak, W.	*1974*	:	*The behavioural regulation of milieu interne in Man and Rat. Science, 185 : 824-831.*
Garcia, J., McGowan, B.K. & Green, K.F.	*1972*	:	*"Biological constraints on conditioning". In A.H. Black & W.F. Prokasy (Ed.), "Classical conditioning II; Current Theory & Research", Appleton-Century-Crofts, Meredith Corporation, New York, pp. 5-27.*
Gibbons, J.D.	*1971*	:	*Non-parametric statistical inference. (McGraw - Hill Co., New York).*

Girish, G.K., Singh, K., Srivastava, P.K. & Krishnamurthy, K. 1972 : Susceptibility of Rattus rattus to different anticoagulants. Bull. Grain. Technol., 10(2) : 113-115.

Guttman, N. 1954 : Equal reinforcement values for sucrose and glucose solutions prepared with equal sweetness values. J. Comp. Physiol. Psychol., 46 : 414-418.

Hagstrom, E.C. & Pfaffmann, C. 1959 : The relative taste effectiveness of different sugars for the rat. J. Comp. Physiol. Psychol., 52 : 259-262.

Harriman, A.E. & MacLeod, R.B. 1953 : Discriminative thresholds of salt for normal and adrenalectomized rats. Amer. J. Psychol., 66 : 465-471.

Harris, K.L. 1969 : Proceedings of the Indian Rodent Symposium, 1966, Calcutta.

Harrison, J.L. 1949 : Effect of rain on feeding of the Malayesian rice-field, rat. Nature, 164 : 746-748.

Harrison, J.L. 1954 : The natural food of some rats and other mammals. Bull. Raffles, Mus., 25 : 157-165.

Harrison, J.L. & Woodville, H.C. 1949 : Variation in size and weights in five species of house rats (Rodentia, Muridae) in Rangoon, Burma. Rec. Indian Mus., 47 : 65-71.

Harrison, J.L. & Woodville, H.C. 1950 : Notes on the feeding habits of house rats in Rangoon, Burma. Ann. Appl. Biol., 37 : 296-304.

Htun, P.T. & Brooks, J.E. 1979 : Laboratory evaluation of zinc phosphide as a rodenticide against Bandicota bengalensis. PANS, 25(3) : 246-250.

Jackson, W.B. 1965 : Feeding patterns in domestic rodents. Pest. Control, 33 : 112-114.

Jackson, W.B. 1971 : Biology and Ecology of rodent populations. Proc. & Recomm. of International Symp. on Bionomics and Control of Rodents, Kanpur, pp. 41-50.

Jain, A.P.. Prakash, I. & Rana, B.D. 1974 : Baits for the control of the soft furred field rat, Rattus meltada pallidior Ryley. Zeit. angew. Zoologie, 61 : 183-190.

Jehangir, Emperor 1605 - 1627 : "Tuzuke Jahangiri" II, pp. 261-262. Published by Sir Syed Ahmad Khan, Aligarh.

Kalat, J.W. & Rozin, P. 1973 : "Learned safety" as a mechanism in long delay taste-aversion learning in rats. J. Comp. Physiol. Psychol., 83 : 198-207.

Kamal, A. & Khan, J.A. 1977 : Food preferences of the Indian mole rat, Bandicota bengalensis (Gray). Proc. Indian Acad. Sci., B 86:329-336.

Kapoor, I.P., Ramasivan, T. & Krishnamurthy, K. 1965 : Studies on the bird and rodent control in rice mills. Bull. Grain Technol., 3 (51-55).

Khan, J.A. 1974 : Laboratory experiments on the food preferences of the black rat (Rattus rattus L. Zool. J. Linn. Soc., 54 : 167-184.

Khan, Z. & Khan, J.A. 1979 : Food preferences of five striped squirrel, Funambulus pennanti pennanti Wroughton. M.Phil. Thesis, AMU, Aligarh.

Koh, D.S. & Teitelbaum, P. 1961 : Absolute behavioral taste thresholds in the rat. J. Comp. Physiol. Psychol., 54 : 223-229.

Krishndkumari, M.K. 1968 : Studies on rodenticides and rodent repellents with special reference to the control of black rat (Rattus rattus). Ph.D. Thesis.

Krishnakumari, M.K., Muktabai, K., Yashoda, L. Urs. and Majumdar, S.K. 1971 : Emulsified Fumigant as a Rodent Burrow disinfestant. Proc. Int. Symp. on Bionomics and Control of Rodents, Kanpur, pp. 116.

Krishnamurthy, K. 1968 : Studies on rodents and their control. I. studies on rat populations and losses of food and food grains. Bull. Grain. Technol., 5(3) : 147-153.

Krishnamurthy, K., 1968 Uniyal, V. & Pingale, S.V. : Studies on rodents and their control. 4. Susceptibility of Rattus rattus to warfarin. Bull. Grain Technol., 4(3): 133-137.

Krishnamurthy, K., 1969 & Uniyal, V. : Studies on rodents and their control. 5. Some factors affecting lethal feeding period with warfarin. Bull. Grain Technol., 7(1) : 1-8.

Krishnamurthy, K., 1971a Ramasivan. T. & Uniyal, V. : Studies on rodents and their control part 6. Studies on fluctuation in population and breeding period of Rattus rattus in Hapur region. Bull. Grain Technol. 9(2) : 79-82.

Krishnamurthy, K., 1971b Ramasivan, T. & Singh, D.P. : Studies on rodents and their control, part 7. Effect of impurities in warfarin on its acceptability and mortality to black rats, Rattus rattus. Bull. Grain Technol., 9(4) : 252-256.

Krishnaswami, A.K., Rao. C.K., & Ravindran, P.C. Chandrahas, R.K., Samuel, D. 1972 : Investigations on plague foci in Mahasu district of Himachal Pradesh. Ind. J. Med. Res., 60(8) : 1126-1131.

Kumari, P.V. & Khan, J.A. 1978 : Food preferences of the gerbil, Tatera indica indica Hardwicke. Zool. J. Linn. Soc., 64 : 51-58.

Lehner, P.N. 1979 : Handbook of Ethological methods. Garland TPM Press, New York and London.

Leslie, P.H. & Ranson, R.M. 1954 : In "Control of rats and mice", Vol.II. (Clarendon Press, Oxford) pp.335-349.

Majumdar, S.K., Krishna Kumari, M.K. & Krishnarao, J.K. 1964 : Malathion as a repellent for rats. Curr. Sci., 33(7) : 212-213.

Majumdar, S.K., Krishnakumari, M.K. & Muktabai, K. 1969 : A critical appraisal of rodenticides. Proc. Ind. Rod. Symp., Calcutta, pp. 264-280.

Majumdar, S.K., Krishnakumari, K. & Urs, Y.S. 1969 : Some observations on food preferences and intake of rats under different ecological conditions. Proc. Indian Rodent Symp., pp. 124-136.

McCleary, R.A. 1953 : Taste and post-ingestion factors in specific hunger behaviour. J. Comp. Physiol. Psychol., 46 : 411-421.

Muktabai, K., Krishnakumari, M.K., & Majumdar, S.K. 1971 : Magnesium ammonium arsenate as a rodenticide. Proc. International Symp. on Bionomics and Control of Rodents, Kanpur, pp. 118-119.

Nimbkar, Y.S., Karbhari, R.S., Renapurkar, D.M. & Sant, M.V. 1971 : Observations on susceptibility status of rats from different localities in Thana district to experimental plague infection and serological studies for detection of foci of infection among domestic rodents. Ind. J. Med. Res., 59(8) : 1203-1208.

Nimbkar, Y.S., Karbhari, R.S., Renapurkar, D.M. & Sant, M.V. 1973 : Studies in plague : susceptibility of rats to plague and presence of antibodies to plague in rat sera. Bull. Haffkine Trot., 1(2) : 17-22.

Parrack, D.W. 1967 : A bibliography on rodent literature with emphasis on India. Johns Hopkins CMRT, Calcutta.

Parrack, D.W. 1969 : Food consumption in three common Indian rodents. Proc. Indian Rodent Symposium Calcutta, pp.137.

Patnaik, K.C. 1969 : Rodents in problems of food and health in India. Proc. Indian Rodent Sympsium, Calcutta, pp. 4-8.

Pfaffmann, C., Young, P.T., Dethier, V.G., Richter, C.P. & Stellar, E. 1954 : The preparation of solutions for research in chemoreception and food acceptance. J.Comp. Physiol. Psychol., 47 : 93-96.

Prakash, I. 1963 : Zoogeography and evolution of the mammalian fauna of Rahasthan desert. Mammalia, 27 : 342-351.

Prakash, I. 1976 : Rodent pest management principles and practices. CAZRI, Monograph No.4.

Prakash, I, & Jain, A.P. 1971 : Bait-shyness of two gerbils, Tatera indica indica Hardwicke and Meriones-hurrianae Jerdon. Ann. Appl. Biol., 69 : 169-172.

Prakash, I. & Jain, A.P. 1971 : Toxicity of norbormide for desert rodents. Proc. Int. Symp. on Bionomics and Control of Rodents, Kanpur, pp. 146-149.

Prakash, I. and Mathur, R.P. 1979 : Efficacy of chlorophacinone for the control of Indian desert rodents. Pesticides, 13(6) : 44-46.

Prakash, I., Rana, B.D. & Jain, A.P. 1975 : Baitshyness in three species of Rattus. Zeit. angew. Zoolgie, 62 : 89-97.

Prakash, S. 1954 : Note on natural parasitic infections found in rats in Delhi municipal area. Ind. J. Malar., 8 :115-116.

Rajagopalan, P.K. 1971 : Breeding behaviour and development of Rattus rattus Wroughtoni Hinton, 1919 (Rodentia - Muridae) in the laboratory. J. Bombay nat. Hist. Soc., 67 (3) : 552-558.

Rajagopalan, P.K., Sreenivasan, M.A. & Paul, S.D. 1970 : A note on the arboreal nests of some rodents. Indian J. Med. Res., 58(9) : 1192-1194.

Rana, B.D. & Mathur, R.P. 1980 : Toxicity and relative acceptability of RH-787 to Rattus rattus and Rattus meltada. Protection Ecology, 2(4) : 231-235.

Rao, M.S., Rao, M.N. & Rajaram, M.J. 1977 : Studies on warfarin-Baiting on field & commensal Rats in Maharashtra. Proc. All India Rodent Seminar, Ahmedabad, Sep. 23-26 pp. 155-161.

Rao, R. 1947 : Role of field rats in the endemicity of Plague in H.E.H. Nizam's Dominion. Indian Medical Gazette, 82 : 96.

Renapurkar, D.M. 1971 : Plague epidemiological studies in Nasik district, Maharashtra State. J. Commun. Dis., 3(3-4) : 182-189.

Renapurkar, D.M. & Sant, M.V. 1974 : Laboratory trials of a new rodenticide RH-787. Bull. Haffkine Inst., 2(3) : 123-125.

Richter, C.P. 1939 : Salt taste threshold of normal and adrenalectomized rats. Endocrinology, 24 : 367-371.

Richter, C.P. & Campbell, K.H. 1940 : Taste thresholds and taste preferences of rats for five common sugars. J. Nutrition, 20 : 31-46.

Rosenzueig, M.L. & Sterner, P.W. 1970 : Population ecology of desert rodent communities : body size and seed-husking as basis for heteromyid co-existence. Ecology, 51 : 217-227.

Rozin, P. & Kalat, J.W. 1971 : Specific hungers and poison avoidance as adaptive specialisations of learning. Psychol. Rev., 78 : 459-486.

Rzoska, J. 1954 : The behaviour of white rats towards poison baits. In D. Chitty (Ed.) The Control of Rats & Mice, 1 & 2 : Clarendon Press, Oxford.

Schein, M.W. & Orgain, H.. 1953 : A preliminary analysis of garbage as food for the Norway rat. Am. J. Trop. Med. and Hyg., 2 : 1117-1130.

Seal, S.C. 1960 : Epidemiological studies of plague in India. 2. The changing pattern of rodents and fleas in Calcutta and other cities. Bulletin World Health Organization, 23 : 293-300.

Seal, S.C. 1961 : Epidemiological studies on plague in Calcutta. III. The role of domestic and peridomestic rodents in the maintenance of plague infection and variation in virulence of the organism. Ind. J. Med. Res., 49(6) : 1019-1038.

Seal, S.C. & Banerji, R.N. 1969 : Changing patterns of rodent population in Calcutta & Howrah. Proc. Indian Rodent Symposium, 1966, Calcutta, pp. 69-83.

Sharma, D.R. & Sivaram, S.	1966	:	Nest building by the common house rat, Rattus rattus. J. Bombay Nat. Hist. Soc., 62(3) :548.
Sharma, V.K., Kaura, Y.K. & Singh, I.P.	1970	:	Arizona infection in snakes, rats and man. Ind. J. Med. Res., 58 (4) : 409-412.
Shorten, M.	1954	:	The reaction of the brown rat towards changes in its environment. In D. Chitty (Ed.), "The Control of Rats and Mice", Vol.2. Clarendon Press, Oxford.
Shuford, E.H.	1959	:	Palatability and osmotic pressure of glucose and sucrose solutions as determinants of intake. J. Comp. Physiol.PSychol., 52 : 150-153.
Siddiqui, J.A. & Khan, J.A.	1979	:	Food preferences of soft furred field rat Millardia meltada pallidior Ryley. M.Phil. Thesis, AMU, Aligarh.
Singh, S.M., Harris, H.M. & Batra, H.N.	1965	:	Campaign against rats taken up in Hathras Block I.A.D.P. District Aligarh (U.P.). Plant Prot. Bull., 17(1/2) : 30-33.
Smith, C.C. & Follmer, B.	1972	:	Food preferences of squirrels. Ecology, 53 : 82-91.
Soman, D.W.	1950	:	The incidence and distribution of murine typhus amongst Bombay rats. Indian Med. Gaz., 85 : 249-253.
Sood, M.L. & Dilber, D.S.	1980	:	Vacor - a new rodenticide for the control of rodents. Acceptability to Rattus rattus (Linn.) and Golunda elloti (Gray) in laboratory conditions. Pesticides, 14(7) : 30-32.
Southwick, C.H.	1969	:	Reproduction, Mortality and Growth of murid rodent populations. Proc. Indian Rodent Symposium, Calcutta, pp.152-176.
Spillet, J.J.	1968	:	The ecology of the lesser bandicoot rat in Calcutta. Bombay Natural History Society, Bombay.

Spillet, J.J.	1969	:	Growth of three species of Calcutta rats. Proc. Indian Rodent Symp., pp. 177-196.
Suri, J.C.	1977	:	Rodents and public health : Plague in India. Proc. All India Rodent Seminar, Ahmedabad, pp. 40-45.
Taylor, K.D. & Green, M.G.	1976	:	The influence of rainfall on diet and reproduction in four African rodent species. J. Zool. Lond., 180 : 367-389.
Tewari, K.K. & Biswas, B.	1969	:	Taxonomy and distribution of common Indian rodents. Proc. Indian Rodent Symposium, Calcutta, pp. 9-45.
Tewari, K.K., Ghose, R.K. & Chakraborty, S.	1971	:	Notes on the collection of small mammals from Western Ghats with remarks on the status of Rattus rufescens (Gray) and Bandicota indica malabarica (Shaw). J. Bombay Nat. Hist. Soc., 68(2) : 378-384.
Tirumalarao, V.	1950	:	Rat menace to paddy and other crops: control by poison baiting. Plant Prot. Bull. (Ind.), 1(2/3): 18-19.
Watson, J.S.	1954	:	"Control of the Ship Rat". In D. Chitty (Ed.), "The Control of Rats and Mice", Vol.2. Clarendon Press, Oxford, pp. 490-499.
Watson, J.S. & Perry, J.S.	1954	:	Experiments on rat control in Palestine and the Sudan. In D.Chitty (Ed.), "The Control of Rats and Mice", Vol.2. Clarendon Press, Oxford, pp. 500-516.
Young, P.T., & Madsen, C.H.	1963	:	Individual isohedons in sucrose - sodium chloride and sucrose - saccharin gustatory areas. J.Comp. Physiol. Psychol., 56 : 903-909.

LIST OF PUBLICATIONS

1. Food requirement of "black rat", *Rattus rattus* L. J. Bombay Nat. Hist. Soc., 1976, 71: 605-608.

2. Mitigating poison and bait-shyness developed by wild rats (*Rattus rattus* L.) : Effect of poisoning at short intervals. Indian J. Exp. Biol., 1977, 15: 624-626.

3. Sugar preferences of "black rats", *Rattus rattus* L. Zool. J. Linn. Soc., 1978, 64: 41-50.

4. Effect of texture on the food preferences of bait-shy wild rats (*Rattus rattus* L.) II. Proc. Indian Acad. Sci, 1978, B 87 : 77-80.

5. Effect of texture of food on bait-shy behaviour in wild rats (*Rattus rattus* L.). Appl. Anim. Ethology, 1979a, 5: 361-367.

6. Responses of roof rat, *Rattus rattus* L. to non oily and oily foods after poisoning in oily foods. Proc. Indian Acad. Sci., 1979b, B 88: 125-129.

7. Responses of *Rattus rattus* L., to foods previously used in a mixture for poisoning with zinc phosphide. Proc. Indian Acad. Sci., 1980, B 89: 215-219.

Zoological Journal of the Linnean Society, 64: 41–50. With 6 figures

September 1978

Sugar preferences of "black rats", *Rattus rattus* L.

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Accepted for publication February 1977

The choice of "black rats", *Rattus rattus L.*, for common sugars—sucrose, jaggery, glucose, fructose and lactose are described. In laboratory colonies, the sugars were preferred in the order glucose > sucrose > jaggery > fructose > lactose; but in another sequence—sucrose > jaggery > glucose > fructose > lactose, in the free living colonies. The discrepancy is accounted for by the characteristics of sugars which influence consummatory behaviour in the two situations.

CONTENTS

INTRODUCTION

Selection of sweet foods has adaptive value (Garcia, Hankins & Rusiniak, 1974), and it may be quite general among mammals. However, the preferences from among sweet foods, such as sugars, is adequately known only for the laboratory rat *Rattus norvegicus* (Hagstrom & Pfaffmann, 1958). Wild rats, *R.*

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norvegicus and *R. rattus*, prefer foods sweetened with sucrose or even saccharin (Barnett & Spencer, 1953; Khan, 1974); but nothing is known about their response to other common sugars. The selection of "black rats", *R. rattus*, from among sucrose, jaggery (Indian shakkar, coarse brown and chemically the same as cane sugar; Everyman's Encyclopedia, 1959), glucose, frutose and lactose, was studied by presenting solutions to both captive and free living colonies.

MATERIAL AND METHODS

Laboratory colonies

"Black rats", *Rattus rattus rufescens*, (dorsally brown and ventrally off-white) were trapped as adults from the flour mills in Aligarh city. Animals were sexed, weighed and housed in bisexual groups in galvanized wire-mesh cages of size 1.12 x 1.0 x 0.32 m. Pregnant females were excluded. None of the females became pregnant during the experiments. The rats received daily a surplus of wheat flour, with cabbage once a week and buffalo's liver fortnightly. Presumably they were eating wheat flour before capture. They drank water from two glass dishes (diameter 12 cm), each holding about 500 ml of water without any danger of spilling. The same dishes contained test solutions when the experiment started. Six days were allowed to each colony for adjustment in the laboratory. A colony was used only for one test, and each test lasted for not less than 5 days.

Free living colonies

(i) A colony of "black rats" infesting a farm building, inside an 18th century Maratha Fortress, was used for field trials. The building comprised of two narrow rooms (2.42 x 2.42, 2.42 x 8.48 m) by the side of approach road, two sizable rooms (4.84 x 5.15, 4.84 x 5.15 m) in the middle, and a row of smaller rooms (3.93 x 2.42, 6.66 x 2.42 m), some interconnected, in the rear (Fig. 1).

Repeated trappings showed the presence of "black rats" only. When the experiments started, in September 1975, most rats were living in one of the big middle rooms packed with a variety of farm implements, sacks of barley and hay. Observation revealed the presence of 13–20 rats on most nights. In February 1976, barley, along with fresh supplies, was transferred to one of the rooms in the rear. Within a few days, all the rats had moved into it, and experiments were continued there.

Both the rooms were deeply tunneled, particularly in the corners. At both places water dishes were placed on the floor, close to the wall bearing the largest number of holes. Sugar solutions replaced water when the tests started. Only water was given between the tests.

(ii) Another colony of "black rats" infesting a grain-store (5.45 x 3.03 m) in the University market, was tried similarly for some tests. It comprised of a single room packed with canisters of salt, spices, pulses and sacks of grains. The rats had free access to whatever was not packed in tins, mostly grains. The size of the population was not known, but the number was smaller than in the colony at fort.

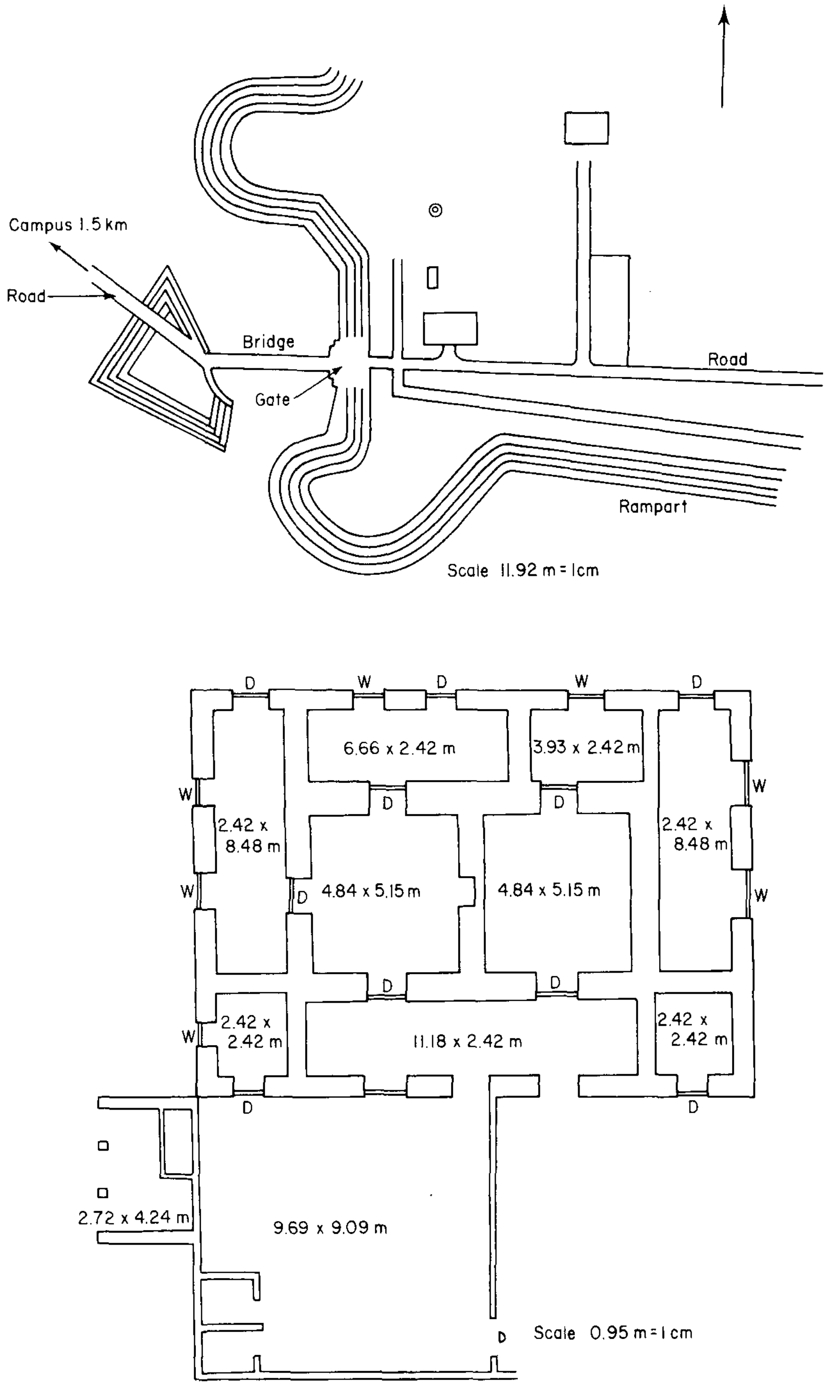

Figure 1. The sketch illustrates the entrance to the Maratha Fortress. The farm building is located on top right. The detailed plan of the building is given in the bottom figure.

Experimental procedure

Reagent quality glucose, fructose, lactose and sucrose were used throughout. Jaggery was purchased from the market. The solutions (5% w/v) were prepared in tap water. The solutions were warmed to 80°C (Pfaffmann *et al.*, 1954), and

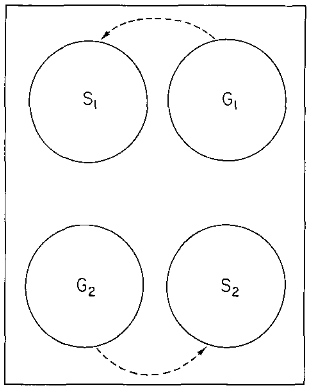

Figure 2. The arrangement of dishes at the field station, containing for example sucrose (S1, S2) and glucose (G1, G2). The position of the dishes was changed daily.

allowed to stand another two hours before use. Fresh solutions were prepared daily.

Two solutions were offered at a time. 500 ml of solution was given in each dish. The residue was measured at the same time next day. Daily intake was measured to nearest 5 ml and a correction was made for loss due to evaporation.

At the farm building and the store, test solutions were each given in two dishes, either facing the wall or holes, or in the rear (Fig. 2).

At field stations glucose was first compared, in successive tests, with fructose, lactose, jaggery and sucrose. In the next series of tests, fructose was similarly given with three other sugars. Lactose was then compared to jaggery, and then to sucrose. The choice consisted of sucrose and glucose in the last test.

Occasionally soil was kicked into the dishes; such findings were discarded. Spillage was checked by placing the dishes in porcelain containers (46 x 32 x 6 cm).

In the cages the position of test solutions was alternated daily, and bias for the contents of a dish in a particular position was never observed. At fort also the positions were interchanged (Fig. 2), and solution of any one kind was never available in the same row or column.

Observations on behaviour

Removal of water dishes at the fort, even for a day, seemed to make the rats very thirsty. They came out to drink whenever the dishes were replaced. An observer (E) then watched them, recording the number of visits and the attempts, if any, to spill the test solutions. Laboratory colonies were similarly watched.

Statistical analysis

Differences in sugar consumption were analysed by Students' "*t*" test (Bailey, 1959). Intakes recorded from each dish at the fort, were compared by 2 x 2 contingency tables (Bailey, 1959), without Sheppard's correction.

Table 1. Mean daily consumption of the field colonies presented with any two of the five sugars

Test no.	Length of test (days)	Choice	Mean daily consumption ml/day ± S.E. Dish 1	Dish 2
1	5	Glucose/Fructose	337.0±43.0/ 85.0±27.8	378.0±41.3/130.0±48.2
2	5	Glucose/Fructose	106.0±24.1/86.0±12.0	105.0±10.8/ 99.0±16.5
3	6	Glucose/Lactose	133.1± 3.6/ 83.3± 5.1	89.1± 5.0/ 74.1± 2.3
4	10	Glucose/Jaggery	129.5±31.2/184.5±27.1	116.5±36.2/232.5±31.1
5	6	Glucose/Sucrose	72.5± 5.3/194.0±17.3	108.0±12.8/199.0±10.3
6	7 Store	Glucose/Sucrose	57.0±11.4/210.0±20.7	82.0±13.7/197.0±25.5
7	4	Glucose/Water	432.2±39.0/ 32.5± 7.7	450.0±11.6/ 26.2± 2.6
8	11	Fructose/Lactose	173.3±18.8/ 72.5± 7.6	140.8±25.2/ 62.0±12.8
9	12	Fructose/Jaggery	114.0±13.7/371.0± 20.9	58.0± 6.1/387.0±25.9
10	7	Fructose/Sucrose		170.1±12.8/413.7±29.2
11	13	Fructose/Water	307.0±60.0/ 57.0±18.2	272.0±32.7/ 73.0±34.5
12	14	Lactose/Jaggery	27.0± 5.4/198.0±13.2	118.0±11.4/263.0±17.2
13	6	Lactose/Sucrose		122.16±14.5/400.5±19.5
14	15	Lactose/Water	218.8±18.0/ 79.0± 7.1	213.0±33.4/100.0±14.0
15	5	Jaggery/Sucrose	62.0±16.0/257.0±10.0	115.0±16.0/233.0±22.6
16	4	Sucrose/Water	388.7±63.5/ 22.5± 2.5	277.5±42.0/ 11.25± 1.2

RESULTS

Loss of test fluids

Rats in laboratory colonies wasted little of the fluids. At fort, however, rats occasionally ran across the dishes or climbed inside when pushed by conspecifics. Such losses could not, however, be measured.

Effect of place preference

In some tests at fort, e.g. when sugar was given with water, the rats drank more from the dishes facing the holes than from those at the rear. A similar association of position and consumption also existed when sugars were given (Table 1). Of the sugar preferred, a higher amount was usually drunk from dish 1, and of the less preferred sugar from dish 2 (Table 1). The obverse was true, however, when jaggery was offered with either fructose or lactose. In any case, the solutions in none of the four dishes were ever ignored. The contents were sampled freely, though particular attention was then directed to dishes containing the more attractive alternatives.

Sampling behaviour

The rats tended to gather round one dish, and drank slowly with intermittent pauses and rapid sniffing. Then some rats left to taste the contents of other dishes, but returned quickly. This behaviour was repeated by all the rats. On one occassion thus, we observed the rats drinking lactose from dish 1 for about an hour before finally dispersing to the dishes containing sucrose, the better choice. The lactose dish was, however, visited repeatedly, but apparently not much was drunk on each visit.

However, rats in laboratory colonies immediately accepted a novel sugar when

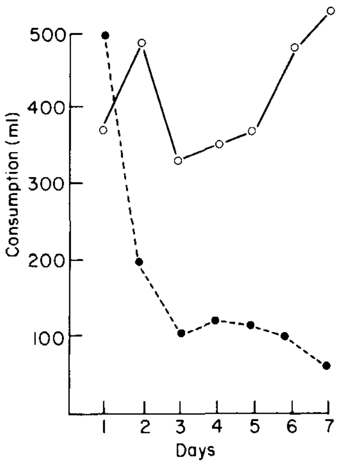

Figure 3. Consumption of sucrose and fructose by the rats at fort. The latter was preferred only on the first day of the test. O, Sucrose; ●, fructose.

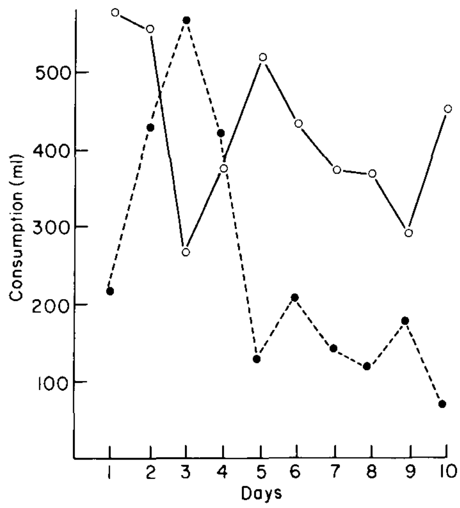

Figure 4. The relative consumption of jaggery and glucose in the field colony at fort. The choice alternated initially but then jaggery was clearly preferred. O, Jaggery; ●, glucose.

a familiar alternative was simultaneously present, or at least consumed it in large amounts. But the fort rats always avoided a novel sugar or when the same sugar was given after a gap of several days. The avoidance persisted for a day or more before the novel choice, if superior, was accepted (Fig. 5).

Sugar preferences of free-living colonies

The rats at the fort, as also in the store, clearly preferred sucrose to glucose ($P > 0.5$). It was consumed in greater amounts on all occasions except in two tests, when more of fructose and jaggery were initially consumed (Fig. 3). In both tests, however, the rats had already been receiving them in some other combination.

Jaggery was also preferred to glucose (Fig. 4), fructose and lactose (Table 1). There were, however, some initial changes in preference when it was tested with glucose. Lactose was almost ignored by the end of the test (Table 1).

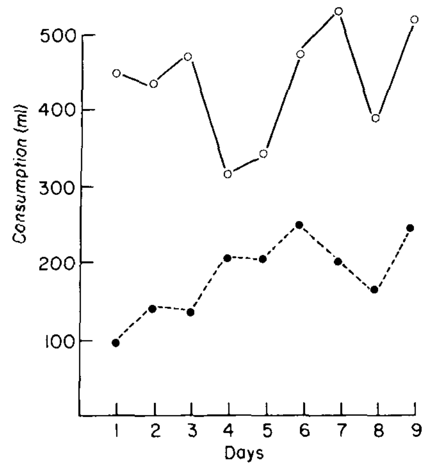

Figure 5. The fort rats clearly preferred lactose to water on all days of the test. O, Lactose; ●, water.

The rats selected glucose in preference over fructose or lactose ($P > 0.5$, Table 1), and fructose over lactose (Table 1). In all tests, including those with lactose, the inferior alternatives were consumed in considerable amounts. When offered with water, lactose, like other sugars, was mainly consumed (Fig. 5). Any aversion for lactose, as evident in laboratory tests (Table 2), was not observed.

Equivocal choices were not observed on any occasion. The sugars tested were clearly preferred in the order sucrose > jaggery > glucose > fructose > lactose (Table 1).

Table 2. The choice of laboratory colonies of black rats for sugars, offered two at a time

Test no.	No. of rats in colony	Length of test days	Mean body wt (g) ±S.E.	Choice	Mean daily consumption ml/day±S.E.	Total consumption ml/100 g body wt/day
1	4	6	188.25± 8.25	Glucose/Sucrose	214.33±23.2 /101.66±16.0	42.0
	4	22	166.0±23.2	Glucose/Sucrose	165.6 ±0.82/134.5±1.54	62.5
2	4	5	166± 6.8	Glucose/Jaggery	204.8±47.8/66.0±7.0	40.0
3	2	8	168.5± 9.2	Glucose/Fructose	91.25±13.6/60.37±9.1	44.0
4	5	5	146.4± 7.7	Glucose/Lactose	365.5±14.3/65.0±7.6	54.8
5	3	6	161.3± 5.0	Glucose/Water	168.5±15.2/30.0±5.0	41.0
6	3	5	151.0± 2.7	Sucrose/Jaggery	168.0±8.4/75.2±17.6	55.0
7	3	9	180.2± 5.2	Sucrose/Fructose	178.0±13.9/138.0±10.3	55.0
8	3	5	161.3± 5.0	Sucrose/Lactose	163.4±24.1/36.0±8.6	43.0
9	3	5	143.0± 9.3	Sucrose/Water	175.0±20.5/46.0±10.5	53.0
10	10	9	90.4± 9.0	Jaggery/Fructose	128.7±14.6/102.22±33.3	25.0
11	5	10	161.4± 7.7	Jaggery/Lactose	176.0±8.6/45.2±6.2	47.0
12	4	6	90.4± 9.0	Jaggery/Water	127.0±8.4/33.3±4.8	44.0
13	10	6	90.4± 9.0	Fructose/Lactose	139.66±19.0/55.0±10.0	22.0
14	7	6	129.1±11.1	Fructose/Water	176.1±10.4/58.0±5.3	23.0
15	2	5	168.5± 5.0	Lactose/Water	38.75±10.4/51.5±2.25	29.0
	2	5	167.0±11.5	Lactose/Water	51.0±2.4/47.8±4.5	29.0

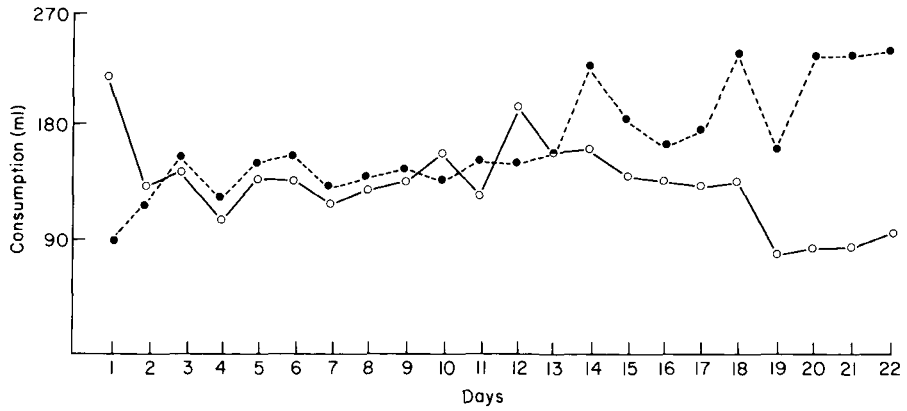

Figure 6. Relative intakes of glucose and sucrose in a laboratory colony of black rats. The choice was equivocal up to the 13th day, but eventually glucose was preferred. ●, Glucose; O, sucrose.

Sugar preferences of laboratory colonies

In some colonies glucose was greatly favoured over sucrose (Table 2). It was, however, only marginally preferred in one colony (Table 2, Fig. 6). Glucose was also selected when compared to fructose ($P > 0.5$; Table 2), though the choice was equivocal on some days. It was, however, consistently preferred to jaggery and lactose ($P > 0.5$; Table 2).

Fructose was preferred to lactose, and also initially to sucrose or jaggery (Table 2). But in the latter tests, the choice soon reversed and did not change subsequently. Sucrose was clearly preferred to jaggery ($P > 0.5$), and both to lactose (Table 2).

The rats in the laboratory selected the sugars in the order glucose > sucrose > jaggery > fructose > lactose. The response to glucose, when compared to sucrose, was rather variable. In other tests, excepting those with lactose, the inferior alternatives were also consumed in significant amounts.

Consumption of lactose, whenever offered, declined with time. Water was drunk equally to it, and in some colonies even in slightly large amounts (Table 2).

Regulation of fluid intake

Regulation of fluid intake was not followed, as the experiments were conducted over a wide range of temperature and humidity. Preliminary trials, however, showed that in the range 18° to 24°C, about 40 ml water/100 g body weight was drunk daily. However, no attempt was made to translate total consumption of fluids at the fort into number of rats.

DISCUSSION

The fort rats, on leaving the burrows, immediately visited the dishes facing their exit points. Larger intakes of test solutions from both or either of these dishes was, therefore, expected (Table 1). It was, however, observed only when the choice was limited to one sugar solution, the alternative being water, when sugars were compared, the contents of all the dishes were sampled freely. That shows their tendency to vary the diet, a behaviour which has great survival value (Barnett, 1969).

The rats at fort and also at the store, showed hesitation in accepting a novel sugar. This behaviour, of "adaptive feeding", was not clearly shown by the rats of the laboratory colonies. Nothing seems to account for this discrepancy; more investigations are apparently needed to clarify it.

The sugars tested vary in their effects on water intake. Sucrose provokes thirst while glucose does not (Beck, 1967). Such effects of the sugars offered, may have also contributed to variations in total consumption of solutions, besides those related to air temperature and humidity. In field tests, it also reflected the variable number of rats visiting the dishes.

The response of laboratory *R. norvegicus* to sugars, is influenced by (i) their taste effectiveness and (ii) their post-ingestive consequences (Guttman, 1954; Richter & Campbell, 1940). In behavioural tests designed to compare sugars on the basis of taste effectiveness, sucrose is preferred to glucose. However, glucose is favoured over sucrose in situations where the two are freely available. Beneficial effects of ingesting glucose then influence consummatory behaviour, and the greater effect of sucrose's taste is masked (Hagstrom & Pfaffmann, 1958).

The sugars were compared by the same method on rats living in two different situations. When restricted to small cages, the "black rats", *R. rattus*, preferred the sugars in order glucose > sucrose > jaggery > fructose > lactose. The fort rats, however, selected the test sugars in the order sucrose > jaggery > glucose > fructose > lactose (Table 1 and 2). Apparently, post-ingestive consequences influence the consummatory behaviour of rats in laboratory colonies while taste sensivity acts alone in case of "black rats" living in wild.

Rejection of lactose in laboratory trials shows that its effects are hardly beneficial (Richter & Campbell, 1940). No such aversion is, however, detected in tests conducted at fort (Table 1). It may be surmized that some natural fats, known to help its assimilation (Richter & Campbell, 1940), might have been available at fort. This is unlikely as the rats there had only barley to eat, which they duly followed wherever it was moved. Only a few could venture outside because of many snakes, monitor lizards and feral cats around. Evidently, its sweet taste, even though weak, attracted the rats. This further demonstrates the influence that taste exerts on consumption in natural conditions.

For the reason, the "black rats" living at fort displayed strong adaptive feeding response, whereas those confined to cages were relatively insensitive.

SUMMARY

Preferences of "black rats", *Rattus rattus L.*, for sucrose, jaggery, glucose, fructose and lactose, based on relative intakes of 5% solutions in two-choice test situations, are described. In laboratory colonies, the sugars are found to have been preferred in the order glucose > sucrose > jaggery > fructose > lactose. However, a colony of "black rats" infesting a farm building, selected them in the order sucrose > jaggery > glucose > fructose > lactose. Apparently, relative sweetness of sugars largely influenced the consummatory behaviour of free-living rats and post-ingestive consequences of those restricted to cages.

ACKNOWLEDGEMENTS

The authors are grateful to Professor S. A. Barnett, Australian National University, Canberra, Australia and Dr P. E. Cowan, CSIRO Fellow, Jodhpur, India, for criticizing the manuscript. Our thanks are also due to Professor S. M. Alam, Head, Zoology Department, A.M.U., for encouragement and facilities. One of us (DB) is grateful to Aligarh Muslim University for financial assistance.

REFERENCES

BARNETT, S. A. & SPENCER, M. M., 1953. Experiments on the food preferences of wild rats (*Rattus norvegicus Berkenhout*). *Journal of Hygiene, 51:* 16–34.

BARNETT, S. A., 1958. Experiments on "neophobia" in wild and laboratory rats. *British Journal of Psychology, 49,* 3: 195–201.

BARNETT, S. A., 1969. The feeding of Rodents. *Indian Rodent Symposium, Calcutta:* 113–123.

EVERYMAN'S Encyclopaedia, 1959.

GARCIA, J., HANKINS, W. G. & RUSINIAK, W., 1974. The behavioural regulation of milieu interne in Man and Rat. *Science, 185:* 824–831.

GUTTMAN, N., 1954. Equal reinforcement values for sucrose and glucose solutions prepared with equal sweetness values. *Journal of Comparative and Physiological Psychology, 46:* 414–418.

HAGSTROM, E. C. & PFAFFMANN, C., 1958. The relative taste effectiveness of different sugars for the rat. *Journal of Comparative and Physiological Psychology, 51:* 259–262.

KHAN, J. A., 1974. Laboratory experiments on the food preferences of the black rat (*Rattus rattus L.*) *Zoological Journal of the Linnean Society, 54:* 167–184.

PFAFFMANN, C., YOUNG, P. T., DETHIER, V. G., RICHTER, C. P. & STELLAR, E., 1954. The preparation of solutions for research in chemoreception and food acceptance. *Journal of Comparative and Physiological Psychology, 47:* 93–96.

RICHTER, C. P. & CAMPBELL, K. H., 1940. Taste thresholds and taste preferences of rats for five common sugars. *Journal of Nutrition, 20:* 31–46.

Proc. Indian Acad. Sci., Vol. 87 B (Animal Science), No. 3, March 1978, pp. 77–80,

Effect of texture on the food preferences of bait-shy wild rats (*Rattus rattus* L.) II.

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Abstract. Black rats, *Rattus rattus* L., poisoned with 0·02% zinc phosphide in whole lentil (*Lens esculenta*) or green gram (*Phaseolus aureus*) did not accept their whole grains again (bait-shyness). No similar aversion was, however, shown to husked grains of lentil or green gram.

Apparently alternative textural states of the two pulses have distinctive tastes, and hence poisoning in one form (whole grains) does not affect the preference for the other form (husked grains). It is thus possible to avoid ' bait-shyness ' by using whole and then husked grains of such pulses for poisoning this pest.

Keywords. *Rattus rattus*; food preferences; textural effects; black rats.

1. Introduction

The black rat is one among several species of wild rats, which rapidly learn to avoid eating a poisonous mixture (poison shyness; Barnett *et al* 1975) and the particular foods used in it as base (bait-shyness). Thus rats surviving a poisoning campign, may not accept the same poison or bait again (Barnett 1975). The study of this behaviour is important in our efforts to eradicate this pest (Chitty 1954).

The baits ordinarily used, cereals or pulses, are available in several forms—whole grains, husked grains, husked and cracked grains and flours in various states of division. There is evidence that cereals have distinctive tastes as grain and flour, and poisoning in cereal flours does not affect the preference of bait-shy rats for respective whole grains (Bharadwaj and Khan, in press).

In our present study, such alteration of taste with texture was examined in the case of two pulses, lentil (*Lens esculenta* Moench) and green gram (*Phaseolus aureus* Roxb.). The rats were poisoned with zinc phosphide in moist whole grains, and then their responses to moist whole and husked forms of the two pulses have been measured.

2. Materials and Methods

Bisexual group of black rats, *R. rattus*, trapped from Aligarh city, were housed in four wire-mesh cages, $1{\cdot}12 \times 1{\cdot}0 \times 0{\cdot}32$ m, with empty tins and straw for nesting. Water was provided *ad lib.*

When the experiments started the first experimental group ($N=6$) weighed 115·0 ±S.E. 14·3g (range: 80–160g), and the control group (N=5) 117·0±S.E. 8·1g

(100–140g). In experiment 2, the mean weight of the experimental colony (N=6) was 100·0±S.E. 8·8g (82–130g), and the control (N=5) 96·0±S.E. 4·3g (82–105g).

Commercial varieties of lentil (*L. esculenta*), green gram (*P. aureus*) and black were gram (*P. mungo* Roxb.) in two forms viz. whole grains and husked, cracked grains, were used as test foods.

Weighed amounts of food soaked in water for 24 hr, drained on wiregauze for 2 hr and weighed again, were presented to the rat colonies. The residue, including spillage, was dried at 80° C for 24 hr and then weighed (Rw). Equivalent amounts of pulses, as controls, were similarly soaked, drained, weighed and then dried for 24 hr and weighed again (Cw). Consumption of each pulse in terms of dry weight was calculated by subtracting from the weight of control the weight of residue each day. The weight of a pulse was nearly doubled on soaking, but there was little variation in dry weights.

3. Experimental procedure

In experiment 1, the rats were offered the choice between husked lentil and black gram for five days and in continuation whole lentil and black gram also for five days. Whole lentil mixed with zinc phosphide (0·02 %, dry weight) and harmless black gram were given on the following six days. In the next 10 days, preference for husked lentil, husked black gram and whole lentil, whole black gram was tested again, each for five days. Control rats received the same foods, without the poison.

The same procedure was followed in experiment 2, except that the choice was between green gram and black gram. Treatment was given in whole green gram. Controls were also run, as in experiment 1.

The choice shown by the experimental rats for each form of the two pulses before and after treatment was compared to choice shown for equivalent forms by the controls. Student's 't' test (Bailey 1959) was used for testing the significance of preferences observed.

4. Results

Some of the rats died during treatment, 160g ♀ *a* 150g ♀ in experiment 1 and 130g ♀ *a* 81g ♀ in experiment 2, but the experiments were continued with survivors. The results are given in table 1. Similar results obtained from other colonies which were greatly decimated by the poison, are not reported here.

In experiment 1, before the poison was presented, husked or whole lentil was preferred to husked or whole black gram (table 1). Similarly, husked or whole green gram was selected when compared to the two forms of black gram (table 1). Controls also preferred lentil to black gram (mean daily intake; 211·6±11·7g husked lentil, 104·0±2·1g husked black gram; 229·5±11·7g whole lentil, 85·8±7·3g whole black gram) and green gram to black gram (mean daily intake: 211·6±1·6g husked green gram, 103·3±6·1g husked black gram; 235·6±14·4g whole green gram, 82·4±9·0g whole black gram).

The whole lentil and green gram were rejected when mixed with zinc phosphide but the consumption of poisonous mixtures was reduced only gradually and that of harm-

Table 1. Consumption by two groups of rats of husked and whole pulses before and after treatment with zinc phosphide in whole pulses.

Expt. No.	Length of test (Days)	Foods offered	Mean daily consumption g/day ± S.E.	% Total consumption
1	5	Husked lentil; Husked black gram	198·0 ± 5·0; 60·5 ± 3·7	77; 23
	5	Whole lentil; whole black gram	213·3 ± 1·7; 109·6 ± 3·2	66; 34
	6	Whole lentil + Poison; whole black gram	45·4 ± 33·0; 119·8 ± 7·5	27; 73
	5	Husked lentil; Husked black gram	113·5 ± 15·0; 22·3 ± 5·4	84; 16
	5	Whole lentil; whole black gram	20·5 ± 3·7; 66·0 ± 5·0	23; 77
2	5	Husked green gram; Husked black gram	201·5 ± 6·0; 66·5 ± 6·4	76; 24
	5	Whole green gram; Whole black gram	211·6 ± 1·6; 107·6 ± 3·7	67; 33
	6	Whole green gram + Poison; whole black gram	42·0 ± 31·2; 124·4 ± 9·3	24; 76
	5	Husked green gram; Husked black gram	114·3 ± 13·3; 27·3 ± 3·7	81; 19
	5	Whole green gram; Whole black gram	14·5 ± 0·71; 116·0 ± 14·0	10; 90

less black gram increased simultaneously (table 1). Thus, during poison treatment the choice in experimental groups became obverse to that observed for harmless equivalents in controls (mean daily intake: 239·5±4·5g whole lentil, 59·0±5·7g whole black gram; 236·0±4·0g whole green gram, 70·5±12·5g whole black gram).

When the pulses were presented again after treatment, but without poison, the whole lentil was consistently avoided in experiment 1 and similarly the whole green gram in experiment 2; and the whole black gram was mainly eaten in both experiments (table 1). In controls, the rats persisted with eating more lentil or green gram rather than black gram (mean daily intake: 215·0±15·1g whole lentil, 13·0±2·4g black gram; 137·5±7·5g whole green gram, 15·0±1·0g black gram). Thus rats of both experiments 1 and 2 did not again prefer the foods in which they were poisoned.

In both experiments, however, husked lentil and husked green gram continued to be preferred to husked black gram (table 1), much like the controls which also showed the same preference as before (mean daily intake: 140·0±24·5g husked lentil, 18·6±6·0g husked black gram; 161·6±20·0g husked green gram, 30·6g husked black gram). This was in contrast to the avoidance response shown by the experimental groups to whole lentil or green gram after treatment (table 1).

5. Discussion

Exposure to poisoned lentil or green gram led to some deaths, clearly due to its ingestion in large amounts. Consumption of poisoned foods was then reduced by the survivors, though it was not stopped completely (table 1). The avoidance obviously followed the development of 'poison-shyness' to zinc phosphide, while continued sampling of its mixtures may have been the result of the delayed action of poison (Barnett *et al* 1975). Zinc phosphide is a relatively slow-acting poison and the response induced by it is not comparable to that obtained with compounds which act quickly, like apomorphine sulfate, and bring about total avoidance in similar situations (Garcia *et al*, 1974).

Following treatment, the rats also became ' bait-shy ', or averse to eating the particular foods in which they were poisoned, whole lentil in experiment 1 and whole green gram in experiment 2 (table 1). Several species of rodents, including the gerbils *M. hurrianae* and *T. indica* (Prakash and Jain 1971) similarly respond to foods treated with zinc phosphide. Our rats, however, did not avoid the alternative forms of the same foods, i.e. husked lentil in experiment 1 and husked green gram in experiment 2 (table 1).

If taste was the basis for such avoidance (Barnett *et al* 1975; Garcia *et al* 1974) then the taste of whole lentil or green gram was obviously distinct from that perceived in husked lentil or green gram. Thus two forms of the same pulse were treated as two different kinds of foods and poisoning in one form (whole grains), therefore, did not affect the preference of the rats to the other form (husked grain). Perhaps the outer seed structures (pericarp and testa) are responsible for such alteration of taste with texture in the case of whole grains which contained them as compared to husked grains, which are devoid of them (Khan 1974). Something very similar has also been observed in case of cereals (Bhardwaj and Khan, in press).

Acknowledgements

The authors are grateful to Prof. S M Alam for necessary facilities. One of us (DB) is thankful to the Aligarh Muslim University, for financial support.

References

Bailey N T J 1959 *Statistical Methods in Biology* (London: English University Press)

Barnett S A 1975 *The Rat: A study in behaviour* (Chicago: Chicago University Press)

Barnett S A, Cowan P E, Radford G G and Prakash I 1975 Peripheral anosmia and discrimination of poisoned food by *Rattus rattus* L; *Behav. Biol.* **13** 183-190

Bhardwaj D and Khan J A Effect of Texture on food preferences of ' bait-shy ' wild rats (*Rattus rattus* L.); *Ann. Appl. Biol.* (in press).

Chitty D 1954 in *Control of Rats and Mice* (Oxford: Clarendon Press)

Garcia J, Hankins W G and Rusiniak K W 1974 The behavioural regulation of the Milieu Interne in man and rat; *Science* **185** 824-831

Khan J A 1974 Laboratory experiments on the food preferences of black rat (*Rattus rattus* L); *Zool. J. Linn. Soc.* **54** 167-184

Prakash I and Jain A P 1971 Bait-shyness of two gerbils, *Tatera indica Hardwicke* and *Meriones hurrianae* Jerdon; *Ann. Appl. Biol.* **69** 169-172

Applied Animal Ethology, 5 (1979) 361—367

EFFECT OF TEXTURE OF FOOD ON BAIT-SHY BEHAVIOUR IN WILD RATS (*RATTUS RATTUS*)

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(Received 10 July 1978)

ABSTRACT

Bhardwaj, D. and Khan, J.A., 1979. Effect of texture of food on bait-shy behaviour in wild rats (*Rattus rattus*). *Appl. Anim. Ethol.*, 5: 361—367.

Colonies of wild rats, *Rattus rattus* L., were offered a choice between millet and wheat, or between cracked lentil and cracked gram. The foods were given first as grains and subsequently in the form of unextracted flours. The rats were then poisoned with zinc phosphide (4 mg/10 g of food) in one of the two flours and again presented with the same choice of unpoisoned foods in the same order as before.

The rats avoided the flours in which they had ingested poison (bait-shyness). In the case of lentil and gram, they also avoided the corresponding husked grain. However, when the rats were poisoned in cereal flour their preferences for one or other of the whole grains remained unaffected. Apparently whole millet and whole wheat were sufficiently different in taste or texture from their respective flours to prevent the rats associating the two. The results indicate the possibility of following such baiting schemes in order to eliminate shyness during control operations against this pest.

INTRODUCTION

Wild rats, *Rattus norvegicus* Berk. and *R. rattus* L., discriminate between a wide variety of foods by their distinctive tastes and textures (Barnett and Spencer, 1953; Khan, 1974). Laboratory rats (and presumably the wild type also) even have some capacity to choose the better of alternative foods (Barnett, 1975). The obverse of this dietary self-selection is "bait-shyness" or the avoidance of toxic foods (Armour and Barnett, 1950; Rosin and Kalat, 1971).

Foods mixed with poison are also discriminated against on the basis of taste (Barnett et al., 1975) and then avoided, even when offered without poison (Prakash and Jain, 1971). One question of practical importance, still to be examined, concerns the development of shyness to textural variants of the same food (e.g. grains in various states of division). If textural variation is not important, then aversion developed for, say, wheat flour would also result in the avoidance of whole wheat.

The present experiments examined the responses of bait-shy rats to changes in the state of division of baits on which they were fed.

METHODS

Subjects were wild-caught stock, acclimatised to laboratory conditions and living in stable colonies. At the time of the experiments, pregnant females and juveniles (<80 g in weight) were excluded, and the adults left in colonies as before. Sex and body-weight of individuals in different colonies are given in Table I.

TABLE I

Weight (g) and sex of rats in the colonies, with record of deaths that occurred following treatment

Exp. no.	Description of colony	Rats		Body weight (g ± S.E.)		Deaths
		Male	Female	Mean	Range	
1	Experimental	1	3	126 ± 3.12	119–131	119 g ♀
	Control	2	5	170 ± 11.51	116–230	—
2	Experimental	1	3	163 ± 5.64	160–190	—
	Control	—	2	125 ± 3.42	116–134	—
3	Experimental	3	15	169 ± 5.67	115–190	155 g♀ 178 g ♂
	Control	1	7	168 ± 15.0	92–226	—
4	Experimental	2	14	142 ± 6.27	110–165	120 g ♀ 100 g ♂
	Control	2	6	143 ± 2.25	130–152	—

Housing consisted of wire-mesh cages, 1.12 × 1.0 × 0.32 m, or tanks, 2.7 × 1.5 × 1.2 m. When not under test, rats were maintained on a standard laboratory diet for rats, as earlier. Water was provided ad libitum and cabbage once a week.

Millet (*Pennisetum typhoides* Burm), wheat (*Triticum aestivum* L.), lentil (*Lens esculenta* Moench) and gram (*Cicer arienatum* L.,), and their unextracted flours, were used as test foods. Weighed amounts were presented in dissection trays (26 × 30 × 8 cm); the residue, including that spilled, was weighed the next day.

In Experiments 1 and 2, rats were offered a choice of millet and wheat grains, and then of millet and wheat flours, each for 8 days. After this, zinc phosphide (4 mg/10 g of food) was added to the millet flour in Experiment 1, and to the wheat flour in Experiment 2. The poisoned food and the harmless alternatives — wheat flour (Experiment 1) and millet flour (Experiment 2) were continuously available during the next 11 days. After that millet and wheat, in both forms, were presented again for 8 days each and in the same order as before. The schedule for the controls was identical except that no poison was added to any of the foods. Intake was recorded daily for the 43 days duration of each experiment.

The same procedure was followed in Experiments 3 and 4 except that husked, cracked lentil and gram replaced the cereal grains, and lentil and gram flours replaced the cereal flours.

Methods described by Bailey (1959) were followed for statistical analysis of the data.

RESULTS

Table II summarises the findings from only one colony of each experiment, as examples of typical results, while those from other colonies have not been presented. The results of Experiments 1 and 3 are also illustrated in Figs. 1 and 2. In most experimental colonies, some of the rats died following the ingestion of poison. The experiments were, however, continued with the survivors.

The results of similar experiments on individually caged rats will be published later.

Selection of test foods

Millet is readily accepted by "black" or "roof" rats in preference to other grains (Khan, 1974). Rats of Experiment 1 also preferred millet or millet flour to wheat or wheat flour. Neither form of wheat was disfavoured, but the flour contributed more to mean daily intake than did the grain (Table II).

In Experiment 2 millet was, however, only marginally more preferred than wheat (Table II), and the rats clearly preferred wheat flour to millet flour. This may reflect their greater experience in the laboratory with wheat flour. Cracked lentil was favoured over cracked gram in Experiment 3, as also observed by Khan (1974). It was, however, even more preferred when offered as flour with the same form of gram (Table II).

The rats of Experiment 4 behaved atypically by favouring cracked gram over lentil. Gram flour was, however, not chosen when compared to lentil flour (Table II). This is exactly the opposite of what happens in the case of cereals, which are usually preferred in a fine state of division (Barnett, 1969; Khan, 1974).

The control rats selected the foods in the same order. This order of preference did not change when the same foods were offered again.

Effect of poisoning

The rats, except in Experiment 4, were given poison in their preferred

TABLE II

Consumption of foods (means ± S.E.) presented to experimental rat groups

Exp. no.	Length of test (days)	Mean consumption of foods offered (g/day ± S.E.)				% total consumption
1	8	Whole millet	47.92 ± 1.13	Whole wheat	1.7 ± 0.11	96; 4
	8	Millet flour	37.53 ± 1.71	Wheat flour	19.13 ± 1.81	66; 34
	11	Millet flour + poison	5.64 ± 3.00	Wheat flour	31.12 ± 2.63	14; 86
	8	Whole millet	20.11 ± 1.53	Whole wheat	2.37 ± 0.35	90; 10
	8	Millet flour	5.12 ± 1.30	Wheat flour	27.90 ± 1.40	16; 84
Control	8	Whole millet	96.60 ± 6.70	Whole wheat	8.20 ± 1.20	92; 8
	19	Millet flour	68.30 ± 7.60	Wheat flour	36.60 ± 2.90	65; 35
	8	Whole millet	67.00 ± 4.20	Whole wheat	6.60 ± 0.20	91; 9
	8	Millet flour	61.80 ± 6.20	Wheat flour	31.00 ± 2.10	66; 34
2	8	Whole wheat	22.00 ± 1.60	Whole millet	25.4 ± 3.20	47; 53
	8	Wheat flour	32.80 ± 1.40	Millet flour	20.00 ± 5.40	61; 39
	11	Wheat flour + poison	9.51 ± 0.66	Millet flour	30.21 ± 2.96	23; 77
	8	Whole wheat	24.72 ± 3.54	Whole millet	8.56 ± 1.52	75;25
	8	Wheat flour	5.34 ± 1.32	Millet flour	35.56 ± 2.34	12; 88
Control	8	Whole wheat	17.00 ± 1.27	Whole millet	27.00 ± 4.17	39; 61
	19	Wheat flour	27.00 ± 1.27	Millet flour	11.15 ± 3.46	71; 29
	8	Whole wheat	17.11 ± 1.21	Whole millet	13.11 ± 4.34	57; 43
	8	Wheat flour	20.36 ± 1.25	Millet flour	7.16 ± 0.66	74; 26
3	8	Cracked lentil	114.04 ± 2.55	Cracked gram	50.6 ± 1.41	69; 31
	8	Lentil flour	233.00 ± 9.96	Gram flour	27.6 ± 4.40	90; 10
	11	Lentil flour + poison	30.77 ± 18.31	Gram flour	103.77 ± 12.66	22; 78
	8	Cracked lentil	16.63 ± 1.16	Cracked gram	101.75 ± 1.43	13; 87
	8	Lentil flour	24.37 ± 3.66	Gram flour	93.75 ± 3.00	20; 80
Control	8	Cracked lentil	64.7 ± 9.56	Cracked gram	29.55 ± 2.60	69; 31
	19	Lentil flour	93.81 ± 3.56	Gram flour	31.33 ± 2.27	75; 25
	8	Cracked lentil	88.78 ± 4.28	Cracked gram	15.56 ± 3.18	85; 15
	8	Lentil flour	98.17 ± 2.18	Gram flour	17.37 ± 3.00	85; 15
4	8	Cracked gram	161.67 ± 10.82	Cracked lentil	81.44 ± 4.87	66; 34
	8	Gram flour	78.00 ± 11.56	Lentil flour	152.55 ± 13.56	34; 66
	11	Gram flour + poison	46.80 ± 4.55	Lentil flour	193.04 ± 4.90	20; 80
	8	Cracked gram	91.22 ± 7.77	Cracked lentil	132.81 ± 7.15	40; 60
	8	Gram flour	35.72 ± 3.21	Lentil flour	190.55 ± 5.13	16; 84
Control	8	Cracked gram	72.44 ± 4.40	Cracked lentil	23.22 ± 3.51	76; 24
	19	Gram flour	26.21 ± 4.32	Lentil flour	62.23 ± 6.71	30; 70
	8	Cracked gram	70.23 ± 4.36	Cracked lentil	20.25 ± 2.26	78; 22
	8	Gram flour	19.36 ± 1.88	Lentil flour	74.00 ± 3.36	21; 79

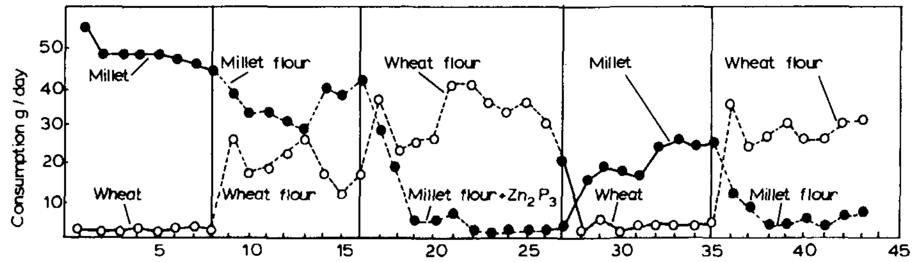

Fig. 1. Experiment 1. Consumption by rats of whole cereal grains or of flours, with or without zinc phosphide, on successive days.

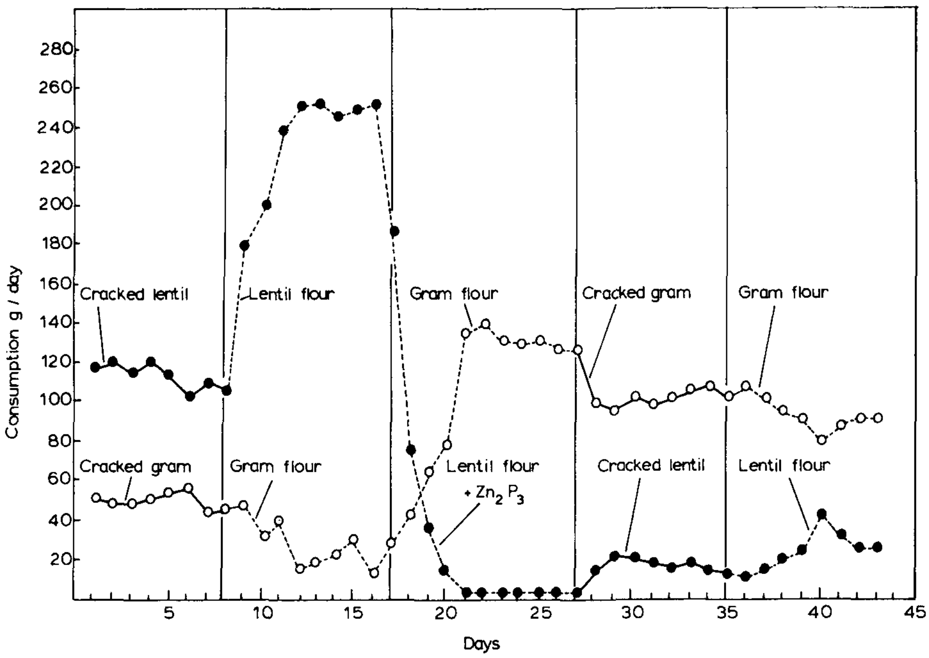

Fig. 2. Experiment 3. Consumption by rats of cracked pulses or of flours, with or without zinc phosphide poison, on successive days.

foods. Consequently, on Days 1 and 2 poisoned foods, e.g. millet flour in Experiment 1 (Fig. 1) and lentil flour in Experiment 3 (Fig. 2), were eaten in large amounts. On the following days, however, intake of poisoned foods was greatly reduced and that of harmless alternatives increased simultaneously. Similarly, gram flour in Experiment 4 became more aversive when mixed with zinc phosphide (Table II). This change in feeding pattern, the obverse of that of controls (Table II), was clear evidence of the avoidance of toxic foods.

Food preferences after treatment

When the choice tests were repeated, the rats rejected the foods to which poison had been added (bait-shyness), namely millet flour in Experiment 1, wheat flour in Experiment 2 and lentil flour in Experiment 3 (Table II, Figs. 1 and 2). Earlier, these foods had been readily accepted, as they still were in the controls (Table II).

The survivors in Experiment 1, however, ate as much whole millet as they had before poisoning (Fig. 1). Similarly, rats of Experiment 2 accepted whole wheat while, unlike controls, avoiding wheat flour (Table II). Poisoning in cereal flours, therefore, did not affect the preference for the corresponding whole grains (Table II).

In Experiment 3, lentil flour and grain were both rejected after poisoning (Fig. 2). Treatment with poison in flour evidently affected the preference for cracked, husked grain, unlike the results of Experiments 1 and 2. Similarly, poison in gram flour led to an increased consumption of lentils (Table II), which were then preferred to cracked gram. The controls, however, continued to accept cracked gram in preference to lentil (Table II).

DISCUSSION

Zinc phosphide is a relatively slow acting poison and its mixtures, especially with such attractive foods as millet flour and lentil flour, are thus avoided only gradually, and never completely ignored (Figs. 1 and 2). The foods in which zinc phosphide has been ingested are, however, afterwards consistently rejected, even when presented in a harmless form. The gerbils *Meriones hurrianae* Jerdon and *Tatera indica* Hardwicke, respond similarly to foods previously mixed with this poison (Prakash and Jain, 1971). The specific tastes, by association with poisoning, apparently become the basis of avoidance.

In Experiments 1 and 2, treatment with zinc phosphide clearly resulted in a complete reversal of choice for cereal flours (Table II; Fig. 1). The rats, however, successfully discriminated between flour and whole grains, and poisoning in flour did not result in rejection of the corresponding grain. Possibly due to the presence of outer seed structures (pericarp and testa), the taste of grains is perceived distinctly from flour. When pericarp and testa are absent, as in husked and cracked lentil and gram, poisoning in one form does affect the preference for another form of the same food (Table II; Fig. 2), or shyness is broadened to alternative forms. Thus, texture is also "sensed", and when the same food is offered in alternative forms, it is confounded with taste.

Present results indicate, therefore, that whole cereal and its corresponding flour can be used successively in poisoning operations during pest control. Pulses can also be used likewise, as whole grains and then in the form of husked, cracked grains (Bhardwaj and Khan, 1978). Then, consecutive treatments with zinc phosphide would not result in any loss in efficacy of the second treatment due to bait-shyness. However, confirmation of this is needed for the much higher concentrations of zinc phosphide (c. 50—500 mg/ 10 g of food) normally used in the field.

ACKNOWLEDGEMENT

The authors are grateful to Prof. S.A. Barnett, Australian National University, Canberra, Australia, for critical comments on the manuscript.

REFERENCES

Armour, C.J. and Barnett, S.A., 1950. The action of dicoumarol on laboratory and wild rats, and its effect on feeding behaviour. J. Hyg., Cambridge, 48: 158—170.

Bailey, N.T.J., 1959. Statistical Methods in Biology. English University Press, London, 200 pp.

Barnett, S.A., 1969. The feeding of Rodents. Proc. Indian Rodent Symp., 1966, Calcutta, pp. 113—123.

Barnett, S.A., 1975. The Rat: A Study in Behaviour. Chicago University Press, Chicago, 2nd ed., 318 pp.

Barnett, S.A. and Spencer, M.M., 1953. Experiments on the food preferences of wild rats (*Rattus norvegicus* Berkenhout). J. Hyg., Cambridge, 51: 16—34.

Barnett, S.A., Cowan, P.E., Radford, G.C. and Prakash, I., 1975. Peripheral anosmia and discrimination of poisoned food by *Rattus rattus* (L). Behav. Biol., 13: 183—190.

Bhardwaj, D. and Khan, J.A., 1978. Effect of texture on food preferences of bait-shy wild rats (*Rattus rattus* L.), II. Proc. Indian Acad. Sci. Sect. B, 78: 77—80.

Khan, J.A., 1974. Laboratory experiments on the food preferences of the black rat (*Rattus rattus* L.). Zool. J. Linn. Soc., 54: 167—184.

Prakash, I. and Jain, A.P., 1971. Bait shyness of two gerbils, *Tatera indica indica* Hardwicke and *Meriones hurrianae* Jerdon. Ann. Appl. Biol., 69: 169—172.

Rozin, P. and Kalat, J.W., 1971. Specific hungers and poison avoidance as adaptive specialisations of learning. Psychol. Rev., 78: 459—486.

Proc. Indian Acad. Sci., Vol. 88 B, Part I, Number 2, April 1979, pp. 125-129,

Responses of roof rat, *Rattus rattus* L., to non-oily and oily foods after poisoning in oily foods

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MS received 6 July 1978; revised 6 November 1978

Abstract. The rats, *Rattus rattus* L., rejected oily foods previously mixed with zinc phosphide; but cereal equivalents, or non-oily foods were avoided only partially. Groundnut oil, though of neutral flavour, also exerted thus some masking effect on the taste of cereal bases.

1. Introduction

Rattus rattus L. develop bait-shyness, or the avoidance of poisonous foods (Barnett 1975). The shyness appears for both poison and bait (Armour and Barnett 1950), which have to be changed in the field after every treatment (Barnett and Prakash 1975). Of the latter, mixtures of cereals and tasteless vegetable oils, e.g., of groundnut (*Arachis hypogea*), are widely used (Prakash 1976). Very little is, however, known about the choice of survivors, or bait-shy rats, to oily and non-oily foods. This was analysed by comparing the preferences of *R. rattus* for oily foods and plain cereal equivalents after poisoning in the former.

2. Materials and methods

2.1. *The rats*

Subjects were wild-caught stock; fed and housed as described earlier (Bhardwaj and Khan 1978). They were weighed and grouped into bisexual colonies; pregnant females and juveniles were excluded. The experiments conducted are termed I (for experiment 1) and II (for experiment 2), etc., throughout this paper. The colony selected for treatment had the mean weight of (i) 171·0 $\pm$ S.E. 10·82 g for I (N = 7), (ii) 150·12 $\pm$ S.E. 23·0 g for II (N = 3) and (iii) 123·71 $\pm$ S.E. 12·75 g for III (N = 3). The control colonies had mean weights of (i) 170·33 $\pm$ S.E. 7·54 g (N = 7), (ii) 107·0 $\pm$ S.E. 9·31 g (N = 4) and (iii) 110·11 $\pm$ S.E. 26·43 g (N = 3) respectively. Replicates were also run.

2.2. *Test foods*

Unextracted flours of millet (*Pennisetum typhoides*), maize (*Zea mays*) and wheat (*Triticum aestivum*) were used as test foods. Groundnut oil was used in concentrations of 5%; and zinc phosphide, as poison at the rate of 0·04%. The weighed foods, two at a time, were given in metal containers; the residue, including spillage, was weighed the next day.

2.3. *Experimental procedure*

In I, wheat flour was compared to millet flour and then to millet flour and oil in two consecutive tests of 8 days each. The rats were poisoned in oily food for 11 days. After this, oily and non-oily foods were again offered. In the former, maize flour and oil was also offered. The same procedure was followed in II and III except the choice between wheat flour and millet flour or millet flour and oil for (II) and maize flour or maize flour and oil for (III) was observed for 4 days each. Poison was given only for 8 days. Unlike I, no new oily food was offered after poisoning. Schedules for controls were similar, but they were not given any poison. Intake was recorded daily for 43 days (I) or 24 days (II and III).

2.4. *Statistical analysis*

Significance of preferences observed was tested by paired t tests (Bailey 1959); and of changes in it by Mann–Whitney U test (Gibbons 1971).

3. Results

Some rats died in I, but no deaths were observed in II and III. Results from only one colony of each experiment are, however, included in table 1.

3.1. *Selection of test foods (non-oily foods)*

Both millet and maize flours were preferred to wheat flour ($P < 0{\cdot}05$; table 1).

Oily foods : Oily foods were similarly preferred ($P < 0{\cdot}05$); millet or maize flour and oil were thus mainly eaten (table 1).

A similar choice was observed in the controls (table 1).

3.2. *Effect of poisoning in oily foods*

The consumption of poisonous millet or maize flour and oil declined on the first day. The avoidance became more obvious on the following days (U tests; $P < 0{\cdot}05$). The rats changed over to eating harmless wheat flour, or the choice was reversed (table 1).

3.3. *Preference observed after poisoning*

Non-oily foods : Millet flour in I and II, and maize flour in III, were again preferred to wheat flour, except on the day after poisoning ($P < 0{\cdot}05$). Unlike in controls, however, both the cereals were now consumed in smaller amounts compared to that observed before poisoning (table 1). Wheat flour was consumed in larger amounts (table 1). Non-oily foods were avoided, but only partially.

Table 1. Consumption of foods (means ± S.E.) offered in rat colonies.

Expt. No.	Length of test (days)	Foods offered	Mean consumption g/day ± SE	% Total consumption
1	8	Millet flour	72·0 ± 7·8	70
		Wheat flour	30·3 ± 4·5	30
	8	Millet flour + Oil	71·7 ± 6·1	72
		Wheat flour	27·2 ± 5·4	28
	11	Millet flour + Oil + poison	11·2 ± 4·6	11
		Wheat flour	93·7 ± 1·4	89
	8	Millet flour	53·8 ± 1·4	52
		Wheat flour	49·7 ± 4·2	48
	4	Maize flour + Oil	67·7 ± 7·8	66
		Wheat flour	34·9 ± 1·3	34
	4	Millet flour + Oil	41·7 ± 6·2	40
		Wheat flour	58·9 ± 7·2	60
Control	8	Millet flour	50·0 ± 9·0	82
		Wheat flour	11·0 ± 5·0	18
	19	Millet flour + Oil	86·3 ± 2·1	73
		Wheat flour	31·6 ± 1·8	27
	8	Millet flour	93·5 ± 6·1	69
		Wheat flour	41·3 ± 3·3	31
	8	Millet flour + Oil	72·0 ± 1·2	75
		Wheat flour	24·0 ± 6·0	25
2	4	Millet flour	32·2 ± 1·3	89
		Wheat flour	4·0 ± 1·5	11
	4	Millet flour + Oil	26·5 ± 0·8	90
		Wheat flour	3·0 ± 0·7	10
	8	Millet flour + Oil + poison	5·5 ± 4·5	25
		Wheat flour	15·0 ± 2·1	75
	4	Millet flour	15·7 ± 3·0	60
		Wheat flour	10·5 ± 0·9	40
	4	Millet flour + Oil	11·0 ± 1·2	36
		Wheat flour	20·0 ± 0·8	64
Control	4	Millet flour	33·0 ± 1·3	92
		Wheat flour	2·0 ± 1·1	8
	12	Millet flour + Oil	26·5 + 1·5	84
		Wheat flour	5·0 ± 1·2	16
	4	Millet flour	23·5 ± 0·6	78
		Wheat flour	6·7 ± 1·3	22
	4	Millet flour + Oil	31·5 ± 1·8	87
		Wheat flour	4·5 ± 0·5	13

Table 1 (*contd*).

Expt. No.	Length of test (days)	Foods offered	Mean consumption g/day ± SE	% Total consumption
3	4	Maize flour	31·2 ± 4·7	74
		Wheat flour	11·2 ± 2·5	26
	4	Maize flour + oil	30·5 ± 1·5	85
		Wheat flour	5·5 ± 0·6	15
	8	Maize flour + oil + poison	5·3 ± 2·5	21
		Wheat flour	19·3 ± 1·2	79
	4	Maize flour	22·0 ± 4·0	53
		Wheat flour	19·5 ± 2·1	47
	4	Maize flour + oil	15·5 ± 0·6	36
		Wheat flour	28·0 ± 1·2	64
Control	4	Maize flour	24·5 ± 1·3	68
		Wheat flour	11·7 ± 1·1	32
	12	Maize flour + oil	27·5 ± 1·5	72
		Wheat flour	10·7 ± 0·5	28
	4	Maize flour	26·5 ± 1·2	71
		Wheat flour	10·3 ± 0·51	29
	4	Maize flour + oil	26·0 ± 1·8	75
		Wheat flour	8·7 ± 0·7	25

Oil foods : In the following tests, however, the rats showed clear bait-shyness, rejecting the foods in which they had ingested poison, namely, millet flour and oil in I and II and maize flour and oil in III (table 1). Earlier the same foods had been greatly favoured, as they still were in the controls (table 1).

Although millet flour and oil was rejected in I, maize flour and oil was much preferred to wheat flour ($P < 0{\cdot}05$: table 1).

4. Discussion

Dry or moist bait mixed with 0·04% zinc phosphide are avoided only gradually by the rats, *R. rattus* (Bhardwaj 1976; Bhardwaj and Khan 1978). Avoidance developed rapidly, however, when this poison was given in oily foods (table 1). Perhaps zinc phosphide was easily ingested and took immediate effect when given in these baits because of the adhesiveness of oil. Thus, the behaviour (poison-shyness) is also influenced by the nature of bait employed.

Poisoning with oil also affected the responses to baits offered subsequently. Shyness developed for oily mixtures (bait-shyness) was not exactly broadened to corresponding cereal bases; and both millet and maize flours were avoided only partially by the bait-shy rats (table 1). It would seem that such discriminations between oily and non-oily foods were made on the basis of their distinctive tastes (Barnett *et al* 1975). It seems, however, more likely that there is only a difference in the strength of taste perceived in the alternative forms.

Thus, groundnut oil has no flavour and at best a neutral taste (Barnett 1969). This is also confirmed by the results of I as maize flour and oil (and not millet flour and oil) was preferred by the rats after poisoning in millet flour and oil (table 1). However, cereal flours have strong and distinctive tastes (Khan 1974). In human beings, however, taste effectiveness of sweet substances is reduced in the presence of non-sweet stimuli (Cameron 1947). Something similar may have occurred in our experiments: and the neutral groundnut oil exerted some masking effect on the taste of cereal bases.

It is, therefore, obvious that bait-shyness developed by *R. rattus* can be reduced, but not eliminated, by poisoning them in cereals with groundnut oil and then in the same baits without it.

Acknowledgements

The authors are grateful to Prof. S A Barnett and Dr P E Cowan, for criticism of the manuscript. One of us (D B) is grateful to the University for financial assistance.

References

Armour C J and Barnett S A 1950 The action of dicoumarol on laboratory and wild rats, and its effect on feeding behaviour; *J. Hyg. Camb.* **48** 158–170

Bailey N T J 1959 *Statistical methods in biology* (London: The English University Press) p. 200

Barnett S A 1969 Feeding of rodents; *Proc. Indian Rodent Symp. Calcutta* pp. 113–123

Barnett S A 1975 *The rat: A study in behaviour* (Chicago: The Chicago University Press) p. 318

Barnett S A, Cowan P E, Radford G G and Prakash I 1975 Peripheral anosmia and the discrimination of poisoned food by *Rattus rattus* L.; *Behav. Biol.* **13** 183–190

Barnett S A and Prakash I 1975 *Rodents of economic importance in India* (New Delhi: Arnold-Heinemann) p. 175

Bhardwaj D 1976 Effect of texture on the food preferences of 'bait-shy' wild rats (*Rattus rattus* L.); M.Phil. Thesis, AMU, Aligarh

Bhardwaj D and Khan J A 1978 Effect of texture on the food preferences of 'bait-shy' wild rats (*Rattus rattus* L.) II.; *Proc. Indian Acad. Sci.* **B87** 77–80

Cameron A T 1947 The taste sense and the relative sweetness of sugars and other sweet substances; *Sugar Res. Found. Sci. Rep. Ser.* No. 9

Gibbons J D 1971 *Non-parametric statistical inference* (New York: McGraw-Hill Co.) p. 167

Khan J A 1974 Laboratory experiments on the food preferences of black rat (*Rattus rattus* L.); *Zool. J. Linn. Soc.* **54** 167–184

Prakash I 1976 *Rodent pest management, principles and practices*; CAZRI, Monograph No. 4 Jodhpur

Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 89, Number 3, May 1980, pp. 215–219.

Responses of *Rattus rattus* L., to foods previously used in a mixture for poisoning with zinc phosphide

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Abstract. Treatments of equivalent wt./wt. mixtures of foods – millet and maize flours, or millet, maize and wheat flours; – with zinc phosphide (4 mg/10 g food) not only make the rats *Rattus rattus* L. averse to eating the original baits, but also their components.

Practical implications of such association of 'bait-shyness' to components of the original baits, are discussed.

Keywords. *Rattus rattus*; food preferences; bait-shyness.

1. Introduction

Roof rats, *Rattus rattus* L. are one of the several species of wild rats that rapidly learn to avoid eating a poisonous mixture and then the particular food used in it as base, or become bait-shy (Bhardwaj and Khan 1977, 1978, 1979a, 1979b). This behaviour has survival value, but is not advantageous (Bhardwaj and Khan 1979b). During control operations against this pest, a change in baits and poisons is thus needed after every treatment (Barnett and Prakash 1975). However, the effects of poisoning rats in mixture of foods, rather than in one particular food, have not been examined. If no shyness develops for individual components, mixtures can be used to obtain additional poisoning before each food is tried separately as base for treatment. If the obverse is true, one poisoning will make several foods ineffective and the use of such baits (Barnett and Prakash 1975), may have to be discouraged. The present study reports the responses of bait-shy rats *R. rattus* towards each component of cereal mixtures on which they were fed.

2. Material and methods

Wild-caught subjects were grouped into colonies and housed in wire-mesh cages, $1 \cdot 32 \times 1 \cdot 0 \times 0 \cdot 32$ m, with wooden boxes and straw for nesting. They were fed before tests on a laboratory rat diet. Water was given *ad lib.* Description of the colonies is given in table 1.

Unextracted flours of millet (*Pennisetum typhoides* Burm), maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), gram (*Cicer arienatum* L.), mixture of millet and maize flour (50 g + 50 g), and millet, maize and wheat flour (50 g each) were used as test foods. Weighed amounts were given in metal containers and the residue, including that spilled, was weighed the next day. The rats were poisoned in mixtures with zinc phosphide at the rate of 4 mg/10 g food.

In experiment 1, the rats were offered millet and maize flour mixture and wheat flour for 5 days. Zinc phosphide was then added to the mixture (4 mg/10 g food). This poisoned mixture and wheat flour were continuously available for the next 7 days. Thereafter, the choice offered consisted of harmless mixture and wheat flour, millet flour and wheat flour, and maize flour and wheat flour. Separate observation was made in tests of 3 days each and the food consumption was measured daily for 21 days.

The same procedure was followed in experiment 2. A mixture of millet, maize, wheat flour and gram flour was given for 5 days. The poisoned mixture with gram flour was given on the following 7 days. The harmless mixture as well as the millet, maize and wheat flour were separately compared to gram flour for 3 days each. Consumption was measured daily for 24 days.

Controls of the two experiments were given the same foods, but they were not given any poison. Replicates were also run simultaneously. The methods described by Bailey (1959) were followed for statistical analysis of results.

3. Results

Results are summarised in tables 2 and 3. Results of experiment 1 are also illustrated in figure 1. Some rats died following the ingestion of poisoned foods, but the experiments were continued with the survivors.

Table 1. Mean body-weight, with standard errors of mean (SE), of rat colonies in expts. 1 and 2.

Description of Colony	No. of Rats		Body wt. (g ± S.E.)		Death
	Male	Female	Mean	Range	
Experimental	1	5	112·50±6·285	90–130	130 g♀
Control	1	4	110·00±6·32	91–132	..
Experimental	1	3	109·25±5·52	90–122	..
Control	1	5	115·60±3·04	109–130	..

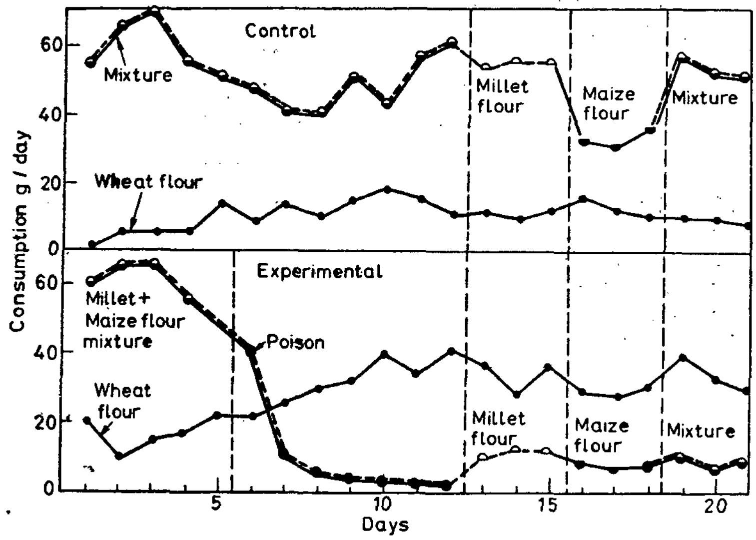

Figure 1.

Table 2. Consumption of foods (g/day ± SE) offered in expt. 1 with standard errors of mean.

Length of test (days)	Food 1	Consumption	Food 2 (Wheat flour)	% consumption
5	Millet + maize flour	65·60 ± 5·12	16·80 ± 2·13	79·61; 20·39
7	Millet + maize flour + poison	8·88 ± 5·42	31·71 ± 2·75	21·72; 78·27
3	Millet flour	9·33 ± 0·76	33·33 ± 2·71	21·84; 78·16
3	Maize flour	7·66 ± 0·405	28·33 ± 0·91	21·29; 78·71
3	Millet + maize flour	7·00 ± 1·14	33·00 ± 2·62	17·50; 82·50
Control				
12	Millet + maize flour	52·50 ± 2·752	9·33 ± 1·32	84·91; 15·09
3	Millet flour	53·33 ± 0·76	9·34 ± 0·76	85·14; 14·86
3	Maize flour	32·33 ± 1·45	10·66 ± 1·76	75·20; 24·80
3	Millet + maize flour	51·66 ± 1·76	7·00 ± 0·57	88·15; 11·85

3.1. *Selection of foods before poisoning*

The rats in experiment 1 preferred millet and maize flour mixture to wheat flour (paired t test, $P < 0{\cdot}05$; table 2), and those in experiment 2 preferred the millet, maize and wheat flour mixture to gram flour ($P < 0{\cdot}05$; table 3). A greater preference was seen for mixtures in controls than in experimental groups but no significant difference was found in the total food consumption ($F_{5,5}$, $P > 0{\cdot}05$).

Table 3. Intake of foods (g/day ± SE) by rats in experiment 2, with standard error of mean.

Length of test (days)	Food 1	Food consumption	Food 2 (Gram flour)	% Consumption
5	Millet + maize + wheat flour	38·41±2·10	11·23±1·51	77·4; 22·60
7	Millet + maize + wheat flour + poison	8·10±4·15	18·30±1·26	30·70; 69·30
3	Millet flour	5·00±1·01	21·00±1·32	18·21; 81·82
3	Maize flour	4·52±1·56	23·55±1·51	16·10; 83·90
3	Wheat flour	7·55±0·15	24·00±1·10	23·8; 76·20
3	Millet + maize + wheat flour	4·00±1·11	21·53±1·00	16; 84
Control				
12	Millet + maize + wheat flour	57·66±2·25	9·51±0·88	85·8; 14·2
3	Millet flour	53·00±3·00	6·51±1·55	89·1; 10·9
3	Maize flour	51·17±1·22	11·13±1·33	82·3; 17·7
3	Wheat flour	52·51±2·54	10·52±0·15	83·3; 16·7
3	Millet + maize + wheat flour	54·00±0·20	8·00±1·31	87·1; 12·9

3.2. *Effect of poisoning*

When poison was added, consumption of mixtures was gradually reduced. Intake of harmless alternatives, wheat flour (experiment 1) and gram flour (experiment 2), was increased simultaneously (tables 2 and 3). However, the rats continued to eat the poisoned foods in very small quantities. The choice of food in the experimental groups was thus reversed. The mixtures were still consistently preferred in the controls, as they were in the experimental groups before poisoning (tables 2, 3).

3.3. *Food preferences after treatment*

After poisoning, the rats in experiment 1 preferred wheat flour to the mixture of millet and maize flour, and to both millet or maize flour offered separately. The rats in experiment 2 similarly preferred gram flour as compared to the millet, maize and wheat flour mixture. Gram flour was also preferred to either of the three baits presented separately without poison. However, the mixtures and their components were preferred to the alternative wheat or gram flour by the respective controls.

4. Discussion

The roof rat, *R. rattus*, prefers cereals to pulses; a linear order of choice is also shown between foods of either category, and both millet and maize flour are preferred to wheat flour (Khan 1974). Thus, superior foods added in a mixture also make more attractive baits than inferior foods offered alone (tables 2, 3).

Even such attractive baits as cereal mixtures were avoided, though not completely ignored, on treatment with zinc phosphide (tables 2, 3). The avoidance obviously followed the development of poison-shyness to zinc phosphide (Bhardwaj and Khan 1977, 1978), while continued sampling of toxic baits indicated the slow aversive action of this poison (Bhardwaj and Khan 1979b). Interference by the learned-safety effect in poison-shyness was not evident (Rozin and Kalat 1971; Barnett *et al* 1975).

After poisoning, the rats became averse to eating the mixtures, or 'bait-shy'. Shyness was also extended to components of the original baits (tables 2, 3). If taste was the basis of such avoidance (Barnett *et al* 1975), then the taste of each food added, *viz.* millet and maize flour in experiment 1 and millet, maize and wheat flour in experiment 2 was distinctly perceived in the mixtures. Their specific tastes by association with poisoning became the basis of avoidance.

Thus, no blending of tastes occurs in cereal mixtures, and the rats are not confounded. Zinc phosphide is, however, used in much higher concentrations in the field (c. 50–500 mg/10 g food), which may result in greater development of bait-shyness. One poisoning in mixtures then would make several foods ineffective restricting the choice in bait-bases needed for second or more treatment with different poisons. When long-term control operations are planned, use of mixtures as base for poisoning with zinc phosphide should be avoided. However, mixtures can be used if a single treatment is desired, or when residual supplies are to be used while other kinds of baits are abundantly available.

Acknowledgements

The authors are grateful to Dr P E Cowan for suggesting the problem. One of us (DB) is grateful to Aligarh Muslim University for financial support.

References

Bailey N T J 1959 *Statistical methods in biology.* (London : English University Press)

Barnett S A, Cowan P E, Radford G G and Prakash I 1975 Peripheral anosmia and discrimination of poisoned food by *Rattus rattus* L.; *Behav. Biol.* **13** 183 190

Barnett S A and Prakash I 1975 *Rodents of economic importance in India* (New Delhi: Arnold-Heinemann Press) 175 pp.

Bhardwaj D and Khan J A 1977 Mitigating poison and bait-shyness developed by wild rats (*Rattus rattus* L.) : Effect of poisoning at short intervals; *Indian J. Exp. Biol.* **15** 624–626

Bhardwaj D and Khan J A 1978 Effect of texture on the food preferences of bait-shy wild rat (*Rattus rattus* L.) II. *Proc. Indian Acad. Sci.* **B87** 77–80

Bhardwaj D and Khan J A 1979a Responses of roof rat, *Rattus rattus* L. to non-oily and oily foods after poisoning in oily foods. *Proc. Indian Acad. Sci.* (Anim. Sci.) **B88** Part I, 125–129

Bhardwaj D and Khan J A 1979b Effect of texture of food on bait-shy behaviour in wild rats (*Rattus rattus* L.). *Appl. Anim. Ethology* **5** 361–367

Khan J A 1974 Laboratory experiments on the food preferences of black rat (*Rattus rattus* L.) *Zool. J. Linn. Soc.* **54** 167–184

Rozin P and Kalat J W 1971 Specific hungers and poison avoidance as adaptive specialisations of learning; *Psych. Rev.* **78** 459–486

Additions

1. Common names "black"rat and "roof" rat have been used interchangeably.

2. Tasting ability demonstrated indirectly testified that zincphosphide mixtures were perhaps discriminated against the taste of poison as well. It has, however, not been (cited) mentioned in text for want of more evidence.

3. Bait-boxes open at both ends, or sides, attracted too many cockroaches, and were, therefore, not used.

4. Effect of texture of food on bait-shy behaviour has since been confirmed by work of Martin & Lawrwnce (1979), Behav.Neural Biol., 27(4), 503-515.

5. The groundnut oil used was of highest purity. Some commercial supplies are suspect, as found by Bhardwaj & Prakash (1979), Z. Angew. Zool., 66 (3), 329-335.